2006 Monitoring of Peirson's Milk-vetch in the Algodones Dunes, Imperial County, California

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Contents

Preface

The author of this report is John Willoughby, State Botanist, Bureau of Land Management (BLM), California State Office. Dunes-wide monitoring of Peirson's milk-vetch that began in 2004 (Willoughby 2005b) was continued and intensified in 2005 (Willoughby 2005c). 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.

Rather than continue the intensive, high-cost monitoring approach used in 2004 and 2005, BLM decided to reduce its level of monitoring effort in 2006 by sampling a randomly selected collection of 25m x 25m cells that were occupied by Peirson's milk-vetch in 2005. This approach was chosen for two major reasons: (1) by the start of winter 2005 it was clear that the 2005-2006 growing season was likely to be a very poor rainfall year; and (2) some of the money saved by reducing the level of effort expended in the direct on-the-ground monitoring of Peirson's milk-vetch could be used to contract for high resolution aerial photography of the Dunes during Presidents' Day weekend 2006, a period of high off-highway vehicle (OHV) use of the Dunes. Reason 1 was important to BLM's decision because previous monitoring has shown that the number of Peirson's milk-vetch plants is positively correlated with the amount of growing season precipitation. Thus, it did not seem prudent to spend approximately $1 million (the amount spent to monitor the species in 2005) to document the fact that many fewer plants occupied the Dunes in 2006. Because the 2004-2005 growing season was extremely favorable for the growth of Peirson's milk-vetch, the 2005 data were invaluable in terms of determining the spatial distribution and abundance in the areas of the Dunes in which the species occurs. In contrast, the 2006 data would simply show what was already expected: that the very low rainfall of the 2005-2006 growing season would produce a relatively small number of plants. This is not to say that some monitoring of the species was not warranted. The sampling approach used in 2006 still allowed for estimates of Peirson's milk-vetch abundance, albeit at lower levels of precision than 2005. Reason 2 was important because part of BLM's monitoring plan for the Dunes calls for the collection of aerial photography that can be used to determine the level of OHV use in different areas of the Dunes and its relationship to Peirson's milk-vetch abundance. This aerial photography can also be used to determine OHV use patterns in Peirson's milk-vetch habitat.

The study was designed by John Willoughby in consultation with Erin Dreyfuss and Chris Knauf [1] of the El Centro Field Office, the BLM office responsible for management of the Algodones Dunes. Jeremy Groom and Tony McKinney of the Carlsbad office of the U.S. Fish and Wildlife Service were also consulted during the design of the study. Erin coordinated every aspect of monitoring implementation. The study would not have been possible without her

[1] Chris now works for BLM in the Oregon State Office.

strong leadership. Chris assisted in driving the sand rail (dune buggy) used to transport the monitors and in logistics (Chris coordinated the monitoring conducted between 2002 and 2005). Steven Lee, Nellie Nutt, Gina Radieve, and Robert Swain, all employees of the Environmental Careers Organization of Boston, Massachusetts, worked with Erin to conduct the actual monitoring. Andrew Trouette volunteered to help with the monitoring that took place in the Wilderness Management Area of the Dunes.

Executive Summary

In late winter and spring 2006, 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. Though the survey began in late winter 2006, it will be referred to simply as the spring 2006 survey hereafter. The 2006 monitoring also included the acquisition of aerial photography on Presidents' Day weekend 2006. This aerial photography was used to determine OHV use patterns in Peirson's milk-vetch habitat and to investigate whether there is a negative correlation between the level of OHV use and the number of Peirson's milk-vetch plants.

The Imperial Sand Dunes Recreation Area Management Plan (ISDRAMP), approved by the BLM California State Director in 2005, established eight management areas.[2] 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, and continued in 2005.

Because rainfall in the 2004-2005 growing season was much higher than average and was well distributed throughout the growing season, the spring 2005 monitoring gave the best picture yet of the distribution and abundance of Peirson's milk-vetch in the Algodones Dunes. In contrast, by the onset of winter 2005 it was clear that rainfall in the 2005-2006 growing season was going to be low, at least for the October-December portion (essentially no rainfall had been recorded in the Dunes following an August precipitation event). Given that previous studies showed a high positive correlation between growing season rainfall and numbers of plants, the decision was made to reduce the level of density and population monitoring in 2006 and to use the data collected in spring 2005 to derive density and population estimates for spring 2006.

A stratified simple random sample of 735 of the 26,116 25m x 25m cells that were occupied by Peirson's milk-vetch in spring 2005 was used to estimate the density and population size of the species in spring 2006. The strata consisted of 15 of the 16 sampling areas used for the 2005 sampling (because Sampling Area 12 in the Buttercup Management Area had so few occupied cells in 2005 it was not sampled in 2006; consequently, density and population estimates for the Buttercup Management Area in 2006 are based only on the cells sampled in Buttercup Sampling Area 11). The sample of 735 cells was allocated to the sampling areas in proportion to the sampling effort afforded them in 2005. 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.

[2] As this document goes to press, the ISDRAMP has not been implemented because of ongoing litigation.

Precipitation in the 2005-2006 growing season was only 10% of average. Most of the little rainfall that did fall in the Dunes fell in March 2006 and did not trigger any significant germination of Peirson's milk-vetch. All of the plants counted in 2006 likely germinated in the 2004-2005 growing season or before.

There were an estimated 83,451 Peirson's milk-vetch plants throughout the seven management areas of the Dunes in 2006. This translates into an estimated density of 3.9 plants/hectare, but the species was not uniformly distributed throughout these seven management areas. The highest estimated density in 2006 was in the Mammoth Wash Management Area (11.4 plants/ha), but this likely results from the fact that many of the cells in that management area were visited early in the monitoring period before the onset of higher, desiccating temperatures. The next highest density was recorded for the Adaptive Management Area (5.6 plants/ha), followed by the Wilderness Management Area (4.8 plants/ha), the Ogilby Management Area (2.8 plants/ha), the Gecko Management Area (2.5 plants/ha), the Glamis Management Area (1.3 plants/ha), and the Buttercup Management Area (1.0 plants/ha). Differences in densities between management areas likely reflect differential mortality during the monitoring period as well as differences in habitat quality and seedbank size. In addition, estimates of total plant density and population size by management area are not very precise, particularly for the Ogilby and Buttercup management areas. Because of these confounding factors, not much should be made of the density differences between management areas in 2006.

Sixty-eight percent of the plants in spring 2006 were flowering at the time of counting. An estimated 56,782 of the dunes-wide estimate of 83,451 plants were flowering adults. Of these, 27,755 or 49% of the total number of flowering plants were considered by the monitors to be more than 1-year old. In fact, it is likely that most of the plants observed during the 2006 survey--both flowering and nonflowering--were either more than 1-year old or approaching 1-year old, because essentially all of the plants counted in spring 2006 probably germinated in the 2004-2005 growing season. This calls into question the consistency of the plant characteristics used to determine whether plants are greater than 1-year old.

The dunes-wide 2006 estimate of 83,451 plants was less than 5 percent of the 2005 estimate of 1,831,076 plants and about 59 percent of the 2004 estimate of 141,800 plants. The majority of plants in 2005 and 2006 were flowering adults, a pattern consistent with that observed in 1998, 1999, 2000, 2001, and 2002. In contrast, almost all of the plants observed in 2003 and 2004 were seedlings or young, nonflowering plants, resulting from the fact that the principal germinating rains in those two years came late in the growing season.

The dunes-wide estimate of total density and population size had a precision of ± 37 percent of the estimated value, which is reasonably precise. However, precisions for the management areas were not very good, ranging from ± 66 percent to ± 136 percent. Dunes-wide estimates of nonflowering seedlings and juveniles and of flowering and past flowering plants were ± 46 percent and ± 32 percent, respectively. The dunes-wide estimate of plants greater than 1-year old was ± 59 percent, but there were nonsampling errors in correctly categorizing 1-year old plants, as discussed above. The precision of dunes-side estimates of the number of plants damaged by OHVs was very poor (± 173 percent), because there were very few plants in the sample that had been damaged.

Aerial photography acquired during Presidents' Day weekend 2006 was used to determine if there is a relationship between the level of OHV use (as measured by vehicle track cover) and the number of Peirson's milk-vetch plants. A stratified random sample of 775 25m x 25m cells that were occupied by Peirson's milk-vetch in 2005 was used to study this relationship using linear regression analysis. Vehicle track cover for each of the sampled cells was measured on the aerial photographs and compared to the number of plants counted in those cells in 2005 (under the reasonable assumption that vehicle use on Presidents' Day weekend 2006 was similar to vehicle use on Presidents' Day weekend 2005 and on other high-use weekends). Although there was a slight negative relationship between OHV use and the number of Peirson's milk-vetch plants, this relationship was not statistically significant ($P > 0.05$). More importantly, only 1 percent of the variability in the number of plants is explained by OHV use. This indicates that other factors that were not examined in this study (e.g., habitat, position in the Dunes, etc.) have a much greater effect than OHV use on the spatial variability in Peirson's milk-vetch abundance.

The 775 cells sampled as part of the regression analysis discussed above were used to create a OHV use pattern map using the process of kriging. The resulting map is produced in this report.

Introduction

In late winter and spring 2006, 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 2006, it will be referred to simply as the spring 2006 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).[3] 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 were reported in Willoughby (2005c). The 2006 results are reported here.

Methods

Density and Population Size

In 2005 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 (these 25m x 25m segments are referred to as "cells" in this document). 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. See Willoughby (2005c) for more information on the design of the 2005 monitoring study.

A total of 123,488 cells were surveyed in 2005, 26,116 of which contained one or more ASMAP plants. In 2006 a stratified simple random sample of 735 of the occupied cells was surveyed for ASMAP plants. The strata were 15 of the 16 sampling areas (because Sampling Area 12 in the Buttercup Management Area had so few occupied cells in 2005 it was not sampled in 2006; consequently, density and population estimates for the Buttercup Management Area in 2006 are based only on the cells sampled in Buttercup Sampling Area 11). The sample of 735 cells was allocated to the sampling areas in proportion to the sampling effort afforded them in 2005. Table 1 shows the number of cells sampled by sampling area in 2006.

[3] As this document goes to press, the ISDRAMP has not been implemented because of ongoing litigation.

Keeping with the protocol originally established in 2003, separate counts were made in each of the sampled cells of the number of ASMAP in each of the 6 categories discussed above for the 2005 monitoring. As in 2005, navigation to each of the cells was accomplished by means of GPS units attached to Hewlett Packard iPAQ Personal Data Assistants running ArcPad Mobile GIS (ESRI 2004).

The plant numbers obtained for the 735 cells surveyed in 2006 were compared to the numbers obtained for those same cells in 2005 by means of ratio estimation using Stata release 9.2 (StataCorp 2006). Because the numbers of plants in 2006 were lower than those obtained in 2005, the ratio estimated was the number of 2006 plants divided by the number of 2005 plants. Separate ratio estimates were obtained for each of the 6 categories of plants and for each of the management areas and the Dunes as a whole. These ratio estimates were then used to estimate the density of plants in 2006 by multiplying the ratio for each of the management areas and the Dunes as a whole by the 2005 density estimates. For example, the density estimate for the Dunes as a whole in 2005 was 5.40 total plants/cell. The ratio estimate (proportion) of the 2006 total number of plants to the 2005 total number of plants was 0.048. The 2006 density estimate was calculated by multiplying 5.40 plants/cell by 0.048, with the resulting 2006 density estimate of 0.26 plants/cell. This density estimate was converted into a total population estimate by multiplying it by the total number of cells in all of the sampling areas of the Dunes.

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 (WRCC) for weather stations in the vicinity of the Dunes. The locations of the RAWS and WRCC weather stations are shown in Willoughby (2004).

Because the sampled population consisted only of cells that were occupied by ASMAP plants in 2005, inferences can technically be made only to the set of 26,116 occupied cells. However, given the very poor 2005-2006 growing season, it was considered unlikely that ASMAP plants would germinate in any of the cells that were unoccupied in 2005. The calculation of 2006 estimates is therefore based on the reasonable assumption that all the cells unoccupied by ASMAP in 2005 would remain unoccupied in 2006. If this assumption is incorrect, the density and population size estimates given in this report will be biased low.[4]

Precipitation graphs were constructed using Microsoft Excel 2003 (Figure 2) and SYSTAT version 10.2 (SYSTAT 2002; Figure 3). Graphs of ASMAP density and population size were constructed using SYSTAT 10.2.

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[4] We considered taking a random sample of all of the cells sampled in 2005, but rejected this based on the likelihood we would have to sample a large proportion of cells with no ASMAP plants. In 2005, 21% of the cells sampled were occupied by ASMAP. Thus, it was considered likely that, in a random sample of all the cells sampled in 2005, about 4 out of every 5 cells sampled would yield no useful information—because the values for the cells would be zeroes in both years. Given the fact that travel time to each of the cells is considerable, particularly in the Wilderness Management Area, where all cells have to be visited on foot, the decision was made to sample only cells that were occupied in 2005 and assume that the cells unoccupied by ASMAP in 2005 would remain unoccupied in 2006. Given the very poor rainfall in the 2005-2006 growing season, this appears to be a reasonable assumption.

Comparison of Vehicle Track Cover to ASMAP Density

True-color aerial photography of the area within all 16 of the sampling areas was acquired on February 19, 2006. This date was chosen because it falls on a Sunday during Presidents' Day weekend, a period of high visitor use in the Dunes. It is estimated that there were about 131,000 visitors to the Dunes that weekend (Neil Hamada, El Centro Field Office, personal communication). This is more use than on all other weekends in the 2005-2006 recreation season except for New Year's weekend, when there were approximately 136,000 visitors, and Thanksgiving weekend, when there were about 192,000 visitors (Neil Hamada, personal communication). The photography was geographically referenced, orthographically corrected, and provided by the contractor, Digital Mapping Inc., in geotiff format. The ground resolution was 4 inches, and the positional accuracy was better than ± 3 meters. A stratified random sample of 775 cells was taken from the 26,116 cells that contained one or more ASMAP plants in spring 2005. A simple random sample of 50 cells was taken from each of the 16 sampling areas, except for Sampling Area 12 in the Buttercup Management Area, where only 25 cells supported ASMAP in 2005; all 25 of these cells were included in the total sample of 775 cells.

A grid of 100 points was superimposed over the aerial photography on each of the 775 cells that comprised the sample. The point grid was 18m x 18m, centered in the middle of each of the 25m x 25m cells that were sampled in 2005. All grids were read at a scale of 1:200 using ArcMap (ESRI 2004). Vehicle track cover was estimated by the point-intercept method (Canfield 1941), by recording whether or not each of the 100 points intercepted a vehicle track. Figure 1 illustrates the grid used; the points are the tops of each of the triangles. The cover for each grid was calculated by dividing the number of points intercepting vehicle tracks by 100 points and then multiplying the result by 100 to convert to a percent. For example, if 39 of the points in a grid intercepted vehicle tracks, the cover for the grid would be 39/100 * 100% = 39%. The grid cover values were then applied to the cells in which the grids were centered.

The percent cover of vehicle tracks for the 775 cells was compared to the number of ASMAP plants counted in those cells in 2005 by means of linear regression analysis. In order to normalize residuals and stabilize variance, natural logs of the count values were used instead of the raw counts. The assumption in this analysis is that vehicle use on Presidents' Day weekend 2006 is a good approximation of vehicle use on Presidents' Day weekend 2005 and, further, that it is a good approximation of vehicle use on other heavy use weekends.

Regression analyses were performed and graphs constructed using Stata release 9.2 (StataCorp 2006).

Vehicle Use Patterns in Peirson's Milk-vetch Habitat

The sample of 775 cells used in the regression analysis discussed above was also used to create a map of vehicle use patterns in the Dunes. This analysis was performed using the Geostatistical Analyst extension to ArcMap 9.1 (ESRI, 2005). The vehicle use pattern map was created using ordinary kriging and a spherical model. The use pattern map was created after arcsin transformation of cover values expressed as proportions. Although there was a west to east linear trend in the data, removing this trend resulted in a more poorly fitted model. Therefore, the default model, with the trend left in, was employed. This model accounted for a W-E directional influence (anisotropy) in the cell values. The lag size employed was 150m, with 10 lags.

Results and Discussion

Weather

Previous BLM monitoring reports (Willoughby 2005b, 2005c) defined the growing season as the period between September 1 and June 30, corresponding to the definition used by Sneva and Hyder (1962) in the Intermountain West (they term this period the “crop-year”). The months of July and August were excluded due to the fact that rain falling in those months as a result of tropical storms from the Gulf of California likely does not promote germination and growth of ASMAP because of the intense heat during those months. Romspert and Burk (1978) demonstrated that germination of ASMAP seed was suppressed at temperatures above 27° C (81° F). Long-term average maximum temperatures at Gold Rock Ranch, the weather station closest to the Dunes (period of record 1964-1996) are 107.0° F and 105.6° F for July and August, respectively. Long-term average minimum temperatures for that same station are 79.6° F and 79.4° F for July and August, respectively.

Phillips and Kennedy (2006) define the growing season for ASMAP as the period between October and April. Based on the data collected by those two authors and BLM’s experience monitoring ASMAP since 1998, the October-April period seems more reasonable than the September-June period formerly considered by BLM to represent the growing season. Elimination of the months May and June from the calculation of total growing season precipitation has little effect on long-term average precipitation values because the long-term average precipitation values for May and June are only 0.03 and 0.01 inches, respectively. Thus, September-June values are essentially equivalent to September-April values. Because the long-term average precipitation for September is 0.33 inches, elimination of September from the calculation of total growing season precipitation has more of an effect on the resulting precipitation value. September is no longer considered to be part of the growing season for ASMAP because of the high temperatures in that month. Long-term average maximum and minimum temperatures at the Gold Rock Ranch weather station are 100.4° F and 73.5° F, respectively. Only in October do the average maximum temperatures drop below 90° F (long-term average 89.9° F).

For the reasons given above, the ASMAP growing season is redefined in this report to be the period between October 1 and April 30. Growing season average precipitation values are used to compare growing seasons to each other and to long-term averages collected from the seven WRCC weather stations in the vicinity of the Dunes.

Table 2 shows the total growing season precipitation recorded by the two RAWS for growing seasons 2002-2003, 2003-2004, 2004-2005, and 2005-2006, and compares the average precipitation for the two RAWS to the long-term average of the WRCC weather stations in the vicinity of the Dunes. Figure 2 shows the monthly precipitation totals recorded by each of the stations for these growing seasons.

Data from BLM's monitoring and from studies conducted by others (Phillips and Kennedy, 2003, 2004, 2005, and 2006; Porter et al. 2005) indicate that ASMAP plants germinating early in the growing season (e.g., October and November) flower and set seed during the following spring, whereas individuals that germinate later in the growing season (e.g., February and March) do not flower and set seed until the next growing season. Less clear are the fates of plants that germinate in either December or January. Porter et al. (2005) observed that plants flowered about 3 months from germination. This suggests that plants germinating in December may flower in March and plants germinating in January may flower in April. March temperatures are still relatively mild on the Dunes (average maximum temperature is 78.0° F), while April temperatures are warmer (average maximum temperature 86° F). Thus, a December cohort would probably have sufficient time to set seed before desiccation took much of a toll, at least in average years. On the other hand, a January cohort, particularly a cohort germinating late in the month, may not have time to set seed before hot weather in late April and May either killed individual plants or triggered dormancy.

Figure 3 shows total precipitation in the Dunes between growing seasons 1964-1965 and 2005-2006, and the amount of precipitation that fell between October-December and January-March in each of those growing seasons. This assumes that plants germinating in the period October-December would flower and set seed in the same growing season, while plants germinating in the period January-March would not set seed until the following growing season.[5]

As Figure 3 shows, the total rainfall for 23 of the last 42 growing seasons was less than the long-term average, 1 of these 23 seasons had less than half but more than one-quarter of the long-term average (poor rainfall years), and 8 of these 23 seasons had less than one-quarter of the long-term average (very poor rainfall years). Three times during the period since 1964, a series of two consecutive very poor rainfall years occurred (growing seasons 1970-1971 and 1971-1972; 1995-1996 and 1996-1997; and 1998-1999 and 1999-2000). The longest series of consecutive below-average rainfall years was 4, which occurred from growing seasons 1973-1974 to 1976-1977. There were 14 growing seasons in which most or all precipitation occurred in the January-March period. Five of these growing seasons (1989-1990, 1995-1996, 1996-1997, 1999-2000, and 2005-2006) had precipitation totals that were so low they likely did not trigger much if any germination of ASMAP. The remaining 9 of these growing seasons probably resulted in germination only or at least principally in the January-March time period. Given the findings of Phillips and Kennedy (2003, 2004, and 2006) and Porter et al. (2005) for the 2002-2003 and 2003-2004 growing seasons, it is likely that few of the seedlings that germinated in these growing seasons survived to reproduce.[6] This late-germination pattern occurred during 3

[5] As more information is collected concerning the fates of plants germinating in January, it may be necessary to modify this graph to include January in the first part of the growing season. The month of April was not included in the graph because of the observations of Phillips and Kennedy (2005) that no plants germinated following an early April rainfall in 2004.

[6] This assumes that a cohort resulting from January precipitation does not reproduce in the same growing season. If further study reveals that January cohorts do in fact reproduce in the same growing season, the number of years in which most germinants likely senesced prior to reproduction would be smaller, as January precipitation was a

consecutive growing seasons between 1979-1980 and 1981-1982 and during two consecutive growing seasons in 2002-2003 and 2003-2004.

As Table 2 shows, rainfall for the 2005-2006 growing season was only 10 percent of the long-term average. A very small rainfall event (0.02 inches at the Cahuilla and Buttercup RAWS) occurred on October 17-18, 2005, with the remainder of the rainfall occurring in a single event on March 11, 2006 (0.24 inches at the Cahuilla RAWS and 0.15 inches at the Buttercup RAWS; see Figure 2). The October rainfall event was insufficient to promote germination and very little germination occurred following the March rainfall event (Phillips and Kennedy 2006).

Density and Population Size

The sample of 735 cells was read by two teams consisting of at least two individuals each. Monitoring began on March 2, 2006, and ended on April 18, 2006. Table 3 shows the number of cells visited by sampling area during each week of the monitoring. Figure 4 shows 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 5 of the 6 categories for each management area and the Dunes as a whole. Data for the category, damage from sources other than OHVs, is not included owing to problems discovered after the data had been collected. This category was intended to highlight insect and/or disease impacts to living plants, but for at least one of the management areas monitors included dead plants in their counts under this category. Because of this, and the likelihood that monitoring crews did not appear to be consistent in counting non-OHV damaged plants, the results from this category are not included in this report.[7] Figures 5-9 are dot graphs and 95% confidence intervals showing estimates of ASMAP density (plants/ha) and total population size for each of the 5 categories.

Figure 10 compares the density and total population size estimates, respectively, for 2003, 2004, 2005, and 2006 (values for 2003 are based on monitoring in the Wilderness and Gecko management areas only).

Distribution and abundance. There were an estimated 83,451 ASMAP plants throughout the seven management areas of the Dunes in 2006. This translates into an estimated density of 3.9 plants/hectare, but as Figure 4 illustrates, ASMAP was not uniformly distributed throughout these seven management areas.

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significant part of the January-March precipitation in several of the 9 years in which January-March precipitation was the principal contributor to the total growing season precipitation.

[7] The fact that dead plants were included in the category, damage from sources other than OHVs, was obvious from the data only for the Buttercup Management Area, where there were more damaged plants tallied than living plants. For the other management areas, it was not possible to determine whether monitors included dead plants in their counts for this category, because fewer damaged plants than living plants were counted. Because, however, estimates of damaged plants varied widely between those management areas, from 14% to 78% of the total number of living plants, it appears that monitoring crews did not consistently count only the living plants that were damaged.

Because management areas are different sizes, density (plants/ha) is a better parameter than population size to use to compare management areas.[8] The highest estimated density in 2006 was in the Mammoth Wash Management Area (11.4 plants/ha), followed by the Adaptive Management Area (5.6 plants/ha), the Wilderness Management Area (4.8 plants/ha), the Ogilby Management Area (2.8 plants/ha), the Gecko Management Area (2.5 plants/ha), the Glamis Management Area (1.3 plants/ha), and the Buttercup Management Area (1.0 plants/ha).

The high ASMAP density in Mammoth Wash relative to the other management areas likely results from the fact that many of the cells in that management area were visited early in the monitoring period. As Table 3 shows, all of the cells in Mammoth Wash Sampling Area 14 were visited in the first and second weeks of monitoring. The estimated density in that sampling area was 17.7 plants/ha compared to a density of 4.9 plants/ha in Mammoth Wash Sampling Area 13, which was visited later during the 8-week monitoring period. Essentially all of the plants counted in the Dunes in 2006 represented a cohort of plants that germinated during or before the 2004-2005 growing season (more on this below) and had to survive through summer 2005 and a 2005-2006 growing season that had extremely low rainfall. As a consequence, many plants likely died during the course of the 8 weeks of monitoring as conditions in the Dunes became even drier. Differences in densities between management areas likely reflect this differential mortality as well as differences in habitat quality and seedbank size. In addition, estimates of total plant density and population size by management area are not very precise, particularly for the Ogilby and Buttercup management areas (Table 4 and Figure 5). Because of these confounding factors, not much should be made of the density differences between management areas in 2006.

Stage-class composition in 2006. Sixty-eight percent of the plants in spring 2006 were flowering at the time of counting. An estimated 56,782 of the dunes-wide estimate of 83,451 plants were flowering adults; of these, 27,755 or 49% of the total number of flowering plants were considered by the monitors to be more than 1-year old. In fact, it is likely that most of the plants observed during the 2006 survey--both flowering and nonflowering--were either more than 1-year old or approaching 1-year old. As discussed above, essentially all of the plants counted in 2006 probably germinated in the 2004-2005 growing season. Those that germinated early in that growing season flowered in spring 2005 and those that survived until the 2005-2006 growing season flowered again in spring 2006. Some of those that germinated late in the 2004-2005 and survived until the 2005-2006 growing season had flowered by the time of monitoring, while others had not. Consequently, most if not all of the 2006 plants should have been scored as greater than 1-year old. The characteristics that have been used to determine whether a plant is greater than 1-year old are size of the stem and, because stems can be quite large even in first year plants if germination occurs early in the growing season, the presence of old leaf scars at the base of the plant. Based on the 2006 experience, it seems likely that the leaf scar characteristic is not as reliable as once supposed. It appears that the only sure means of determining age in this species is by marking and tracking the fates of individual plants.

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[8] 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.

Because of the low precisions associated with many of the management area stage class estimates, particularly the estimates for plants greater than 1-year old (Table 4 and Figures 6-8), relative differences between management areas in stage-class composition are not considered reliable enough to discuss.

Stage-class composition in previous years compared to 2006. The 1998-2002 monitoring (Willoughby 2004) consisted of traversing transects through contiguous square cells that were 0.45 miles on each side. An abundance class was assigned to each cell based on the number of ASMAP plants encountered in the cell. Separate abundance class ratings were assigned to seedlings (a category which includes juvenile, nonflowering plants) and adults (flowering plants). In order to assign these abundance class ratings, observers tallied the number of seedling and adult plants they encountered as they traversed through the middle of each of the cells. Because these tallies were not constrained by a particular belt width, their absolute values cannot be compared, nor can they be used to make statistical inferences to larger areas. They can, however, be used to determine the approximate percentage of plants in the seedling and adult stage classes for the years 1998-2002, and the tallies are used for this purpose in Table 5, which compares the percent of plants that were seedlings (including juvenile, nonflowering plants) at the time of monitoring for the years 1998 to 2006. The actual counts made in belt transects are used for the years 2003-2006.

As Table 5 illustrates, the percentage of plants that were juvenile, nonflowering plants was relatively low in all of the years except for 2003 and 2004, when they comprised almost all of the plants counted.

Differences in density and abundance between 2003, 2004, 2005, and 2006. The results of the 2003, 2004, and 2005 monitoring are reported in Willoughby (2005a, 2005b, and 2005c). Density and population size for 2003, 2004, 2005, and 2006 are illustrated in Figure 10. The dunes-wide 2006 estimate of 83,451 total plants was less than 5% of the 2005 estimate of 1,831,076 plants and about 59% of the 2004 estimate of 141,800 plants. The difference between 2006 and 2005 is not surprising given the extremely low rainfall experienced in the 2005-2006 growing season (only 10% of the long-term average rainfall) compared to the high rainfall of the 2004-2005 growing season (226% of the long-term average rainfall, Table 2). Although the 2003-2004 growing season precipitation was about 110% of the long-term average (Table 2), most of these rains fell in February and April 2004, in contrast to the 2004-2005 growing season, in which rainfall was well distributed between October 2004 and March 2005. Rains late in the growing season, as in 2003-2004, apparently do not stimulate germination to the extent that rains earlier in the growing season do, as evidenced by the much greater germination that occurred in 2004-2005.

The late rains in both the 2002-2003 and 2003-2004 growing seasons resulted in a preponderance of seedling and juvenile nonflowering plants, in contrast to the 2004-2005 growing season, in which early rains resulted in a greater proportion of flowering plants compared to nonflowering plants (Figure 10). Though total numbers of plants were far fewer, the majority of plants in 2006 were flowering. As noted above, this is likely because essentially all of the plants counted in 2006 were survivors from 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 percent of the true total population size at the 95 percent confidence level for each of the management areas. Table 6 shows the precision levels attained for estimates of total population size in each of the management areas and the Dunes as a whole and compares these with the precision levels obtained from the 2005 sampling. Table 4 gives precision levels obtained for the other categories for which estimates were made.

As Table 6 shows, the sampling objective was not achieved in any of the management areas of the Dunes in 2006 (precisions ranged from +/- 66 percent to +/- 136 percent), unlike the situation in 2005 when the sampling objective was achieved in every management area except for the Buttercup Management Area. Although the precision of the 2006 dunes-wide estimate (+/- 37 percent) is fairly close to the 30 percent objective, it too does not meet the objective. We knew going into the 2006 study that we would likely not meet the sampling objective for each of the management areas, but we did think we would meet the sampling objective for the dunes-wide estimate. The reason we did not is likely the result of the fact that the 2005 and 2006 cell values were not nearly as correlated as we had anticipated. The simple correlation coefficient between the 2005 and 2006 cell values was only 0.149. A square root transformation, $\sqrt{(X+0.5)}$, slightly improved the correlation to 0.277, while a natural log transformation, $\log_n(X+1)$, improved it slightly more to 0.328. This level of correlation is too low to provide any tangible benefit in terms of variance reduction over the uncorrelated situation.

OHV effects. The 2006 sampling resulted in an estimate of 566 plants (0.7 percent of the total number of plants) damaged from OHV use, all within the Gecko and Adaptive management areas. This estimate, however, is based on only 5 damaged plants in two cells in the Gecko Management Area and 1 damaged plant in one cell in the Adaptive Management Area. Thus, the precision of this estimate is very low (+/- 173 percent), and the data uninformative.

Comparison of Vehicle Track Cover to ASMAP Density

Figure 11 displays the results of linear regression of the natural log of the total number of ASMAP plants counted in 2005 on the percent cover of vehicle tracks on Presidents' Day weekend 2006. This regression is based on a random sample of 775 cells, stratified by management area (Map 5). Although there is a slight negative relationship between the log total number of ASMAP plants and the cover of vehicle tracks, this trend is not significant at $P < 0.05$ (calculated P value = 0.101). More importantly, the percent cover of vehicle tracks explains essentially none of the variability in the number of ASMAP plants ($r^2 = 0.004$).

The sample of 775 cells included areas that were both closed and open to OHV use in 2005, when the data were collected on number of plants, and in 2006, when the data was collected on OHV use. The Wilderness Management Area has been completely closed to OHV use since 1972. Other areas of the dunes were closed on an interim basis in November 2000 and remain closed as of August 2006 (Map 3). All of the ASMAP sampling areas in the Adaptive Management Area are completely within one of these administrative closures, as are large parts of the sampling areas in the Mammoth Wash and Gecko management areas. Smaller parts of the sampling areas in the Glamis and Ogilby management areas are closed to OHV use. Both of the sampling areas in the Buttercup Management Area are entirely open to OHV use. Map 3 shows the relationship of the administrative closures to the management and sampling areas.

Table 7 shows the number of cells sampled by management area within each of the closed areas, including the Wilderness Management Area and the administrative closures, the number of cells with OHV vehicle track cover greater than 0%, and the percentage of the total number of cells showing vehicle track cover.

Fifty-four (12.2 percent) of the 442 cells sampled within areas closed to OHV use had OHV track cover greater than 0 percent. Twenty-three (43 percent) of these 54 cells had OHV track cover values of 5 percent or less. Compliance with the vehicle closures was greatest in the Wilderness and Adaptive management areas with 0 percent and 3 percent of sampled cells, respectively, showing OHV track cover, and lowest in the Glamis, Ogilby, and Gecko management areas with 45 percent, 50 percent, and 50 percent, respectively, showing OHV track cover.[9] Map 6, discussed in detail in the next section, shows the parts of the administrative closures that have signs of vehicle use.

Given the relatively low level of OHV use in the closed areas, regression analysis was performed only on the cells that were sampled in areas outside of the vehicle closures, assuming that it would be more likely to detect relationships between ASMAP abundance and vehicle use using only the cells for which vehicle use is currently authorized. Figure 12 displays results for the entire dunes (n = 333 cells). The slight negative relationship between the log total number of ASMAP plants and the cover of vehicle tracks is not significant (P = 0.069), and vehicle track cover only explains 1 percent of the variability in ASMAP abundance ($r^2 = 0.010$). A percentile confidence interval around the r^2 value of 0.010 was calculated through 15,000 bootstrap samples using the program Resampling Stats (Simon and Bruce 1999) as implemented in the

[9] Some of the vehicle tracks in the administrative closures may be from BLM law enforcement and emergency vehicles, which are authorized to drive in the administrative closures.

program Statistics101 (Grosberg 2005). This 95% confidence interval ranges from 0.0003 to 0.0372. Thus, even if the true r^2 value were close to the higher confidence limit, less than 4% of the variability in plant numbers would be explained by OHV track cover. This suggests that although vehicle use may have a slight negative effect on ASMAP abundance, other factors that were not examined in this study (e.g., habitat, position in the Dunes, etc.) have a much greater effect on the spatial variability in ASMAP abundance than OHV use.

Even after log transformation of the plant numbers, the regression residuals failed to meet two important assumptions of linear regression, normality and homogeneity of variance. Because of this, the data were analyzed by a randomization method discussed by Manly (2007) and implemented in his program RT version 2.1 (Manly 1997). Fifteen thousand randomization of the set of 333 observations outside of the closures resulted in the conclusion that the slope was not significantly different from 0 when the residuals or the values of the dependent variable were randomized ($P=0.065$ and $P=0.067$, respectively). These randomization values are very close to the values resulting from the linear regression reported above.

Because of the high number and wide spread of log plant abundances at low vehicle track cover values, regressions were run eliminating the cells with low vehicle track cover values, e.g., eliminating cells with track cover values < 10 percent, < 20 percent, and so on. Coefficients of determination remained small and the slope of the regression lines were not significantly different from 0 at $P < 0.05$. Figure 13 shows the data, trend line, and statistics from a regression on cell values with track cover ≥ 40 percent. Again, the slope was not significantly different from 0 ($P=0.591$), and vehicle track cover explained less than 1 percent of the variability in plant numbers ($r^2=0.004$).

Regression analyses were performed separately for each management area on those sampled cells that were outside of vehicle closures (no analyses were performed for the Wilderness and Adaptive management areas because the ASMAP sampling areas within those management areas are entirely closed to OHV use). Coefficients of determination were very low and none of the regression slopes were significantly greater than 0 ($P > 0.05$). The interpretation for each of these management areas is therefore similar to the interpretation for the entire dunes.

Vehicle Use Patterns in Peirson's Milk-vetch Habitat

Map 6 shows the predicted OHV track cover from ordinary kriging of the 775 cell cover values. Because the cell values were randomly selected from within the 16 sampling areas, predicted track cover was constrained by the sampling area boundaries. Most vehicle use is concentrated in the Buttercup, Ogilby, Glamis, and Gecko management areas. It appears from Map 6 and Table 7 that users are respecting the Wilderness Management Area closure and, for the most part, the administrative vehicle closures. The predicted OHV track cover values for the Mammoth Wash administrative closure (Closure 1 on Map 3) and the large central administrative closure (Closure 3 on Map 3, encompassing all of the Adaptive Management Area, the southern parts of the Gecko and Glamis management areas and the very northern part of the Ogilby Management Area) are essentially 0 percent for most of these two closures. Exceptions to this are the extreme northern end of the Mammoth Wash closure, with light predicted use, the extreme northern end of the central closure with light to moderate predicted use, and the extreme southern end of the central closure (in the Ogilby Management Area) with moderate to heavy predicted use. The small closure just south of the large central closure (Closure 4 on Map 3) has moderate to heavy predicted OHV use and the closure south of Highway 78 and north of the central closure (Closure 2 on Map 3) has moderate to heavy predicted use along parts of the margins of the administrative closure. No predictions are made for the small Buttercup administrative closure (Closure 5 on Map 3) because this area is not within the sampling areas.

The predicted use values for the areas near the boundaries of the administrative closures may be biased high because of the contribution of cover values for the cells immediately outside these closures. Sand "highways" have developed around the perimeter of some of the administrative closures, particularly around Closure 2, the northern and southern ends of Closure 3, and the small Closure 4. Because of this, cells outside of but near the administrative closures may have high cover values that increase the predicted use values of areas within the closures (the kriging model does not adjust for the potential influence of the closure signing on vehicle use). Nevertheless, as Table 7 shows, vehicle use is occurring within parts of some of the closures, and track cover cell values within the closures is also being incorporated by the model.

Summary

The 2005-2006 growing season was very unfavorable for the germination and establishment of *Astragalus magdalenae* var. *peirsonii* and was the worst growing season for the species since monitoring to estimate population size and density was initiated in 2003. There were an estimated 83,451 ASMAP plants throughout the seven management areas of the Dunes in 2006. Because rainfall was insufficient to promote any significant germination, most if not all of the plants observed in spring 2006 likely germinated in the 2004-2005 growing season, which was very favorable for growth and establishment of the species. The estimated number of plants in 2006 was less than 5 percent of the number of the spring 2005 estimate. Sixty-eight percent of the plants in spring 2006 were flowering at the time of counting.

Although the precision of the dunes-wide estimated total number of ASMAP plants was reasonable (± 37 percent), precisions for estimates of individual management areas was not (precisions ranged from ± 66 percent to ± 136 percent). The precision of the estimate of the number of plants damaged by OHVs was very poor (± 173 percent) because there were very few plants in the sample that had been damaged.

Although there was a slight negative relationship between OHV use and the number of Peirson's milk-vetch plants, this relationship was not statistically significant ($P > 0.05$). More importantly, only 1 percent of the variability in the number of plants is explained by OHV use. This indicates that other factors that were not examined in this study (e.g., habitat, position in the Dunes, etc.) have a much greater effect than OHV use on the spatial variability in Peirson's milk-vetch abundance.

A map showing predicted OHV use patterns in ASMAP habitat was prepared and is included in this report.

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Table 1. Number of cells sampled in each sampling area in 2006.

Management Area	Sampling Area Number	Number of Cells Sampled in 2006	Area Within Sampling Area (ha)
Mammoth Wash	13	43	668.22
	14	44	668.22
Wilderness	15	43	1,246.46
	16	43	1,246.22
Gecko	3	43	1,891.7
	4	43	1,888.6
Glamis	5	43	1,815.29
	6	43	1,817.87
AMA	7	58	1,362.91
	8	42	1,176.88
	17	63	1,527.49
	18	63	1,527.49
Ogilby	19	63	1,698.49
	20	63	1,698.49
Buttercup	11	38	463.63
	12	0	509.23
Total		735	21,207.19

Table 2. Growing season (October-April) 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	Percent of long-term average (Col. 4/Col 5 * 100)
2002-2003	2.68	1.15	1.92	2.11	65%
2003-2004	2.2	2.46	2.33	2.11	110%
2004-2005	4.87	4.68	4.78	2.11	226%
2005-2006	0.26	0.17	0.22	2.11	10%

Table 3. Number of cells read each week during 2006 by sampling area.

Management and Sampling Area *	Number of Cells by Week **							
	1	2	3	4	5	6	7	8
MW 13			8	20	15			
MW 14	25	19						
Wilderness 15	4					39		
Wilderness 16						43		
Gecko 3				7	17		19	
Gecko 4					26	17		
Glamis 5		21		22				
Glamis 6				5	12	26		
AMA 7		1					38	19
AMA 8		42						
AMA 17		33	30					
AMA 18							63	
Ogilby 19			3	30	30			
Ogilby 20			48	15				
Buttercup 11				38				

* 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.
** Week 1 = Mar. 2-3; week 2 = Mar. 6-10; week 3 = Mar, 13-17; week 4 = Mar. 20-24; week 5 = Mar. 27-31; week 6 = Apr. 1-7; week 7 =Apr. 10-14; week 8 = Apr. 17-18.

Table 4. Spring 2006 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 9.2.

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	5.924	0.645	11.203	7,917	862	14,972	89%
Flowering and past flowering	5.558	1.111	10.005	7,428	1,485	13,370	80%
Total number of plants	11.482	1.756	21.207	15,345	2,347	28,342	85%
Plants > 1 year old	1.516	0.014	3.799	2,026	19	5,077	151%
Plants with OHV damage	0.000	0.000	0.000	0	0	0	0%

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	1.354	0.012	2.724	3,375	29	6,789	101%
Flowering and past flowering	3.444	1.660	5.227	8,584	4,139	13,030	52%
Total number of plants	4.798	1.672	7.951	11,960	4,168	19,819	66%
Plants > 1 year old	1.824	0.005	4.768	4,546	13	11,885	161%
Plants with OHV damage	0.000	0.000	0.000	0	0	0	0%

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	0.196	0.001	0.416	739	3	1,571	112%
Flowering and past flowering	2.311	0.860	3.763	8,738	3,251	14,224	63%
Total number of plants	2.507	0.861	4.178	9,477	3,254	15,795	67%
Plants > 1 year old	0.506	0.107	0.906	1,914	404	3,424	79%
Plants with OHV damage	0.137	0.001	0.394	519	5	1,490	187%

Table 4. Spring 2006 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 9.2.

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	0.255	0.027	0.482	926	98	1,753	89%
Flowering and past flowering	1.020	0.172	1.869	3,708	624	6,791	83%
Total number of plants	1.275	0.199	2.352	4,633	722	8544	84%
Plants > 1 year old	0.329	0.005	0.712	1,195	18	2,585	116%
Plants with OHV damage	0.000	0.000	0.000	0	0	0	0%

AMA

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	1.615	0.247	2.983	9,037	1,384	16,691	85%
Flowering and past flowering	4.015	1.513	6.516	22,461	8,465	36,458	62%
Total number of plants	5.630	1.760	9.500	31,499	9,849	53,149	69%
Plants > 1 year old	2.877	0.377	5.377	16,097	2,107	30,086	87%
Plants with OHV damage	0.008	0.000	0.031	47	1	174	269%

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	1.329	0.015	2.938	4,516	52	9,980	121%
Flowering and past flowering	1.478	0.022	3.423	5,022	74	11,630	132%
Total number of plants	2.808	0.037	6.361	9,538	126	21,610	127%
Plants > 1 year old	0.362	0.004	0.756	1,230	12	2,567	109%
Plants with OHV damage	0.000	0.000	0.000	0	0	0	0%

Table 4. Spring 2006 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 9.2.

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	0.163	0.012	0.503	159	12	489	208%
Flowering and past flowering	0.865	0.033	1.918	841	32	1,866	122%
Total number of plants	1.028	0.045	2.421	1,000	44	2,355	136%
Plants > 1 year old	0.769	0.012	2.035	748	12	1,979	165%
Plants with OHV damage	0.000	0.000	0.000	0	0	0	0%

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	1.258	0.678	1.837	26,669	14,371	38,967	46%
Flowering and past flowering	2.677	1.815	3.540	56,782	38,499	75,065	32%
Total number of plants	3.935	2.493	5.377	83,451	52,871	114,032	37%
Plants > 1 year old	1.309	0.541	2.076	27,755	11,480	44,030	59%
Plants with OHV damage	0.027	0.000	0.073	566	6	1,546	173%

Table 5. Comparison of numbers of ASMAP adults and seedlings between 1998 and 2006. Numbers for 1998-2002 are the numbers of plants tallied in the process of assigning abundance class values to 0.45 mile x 0.45 mile cells. Numbers for 2003-2005 represent the number of plants counted within belt transects. Numbers for 2003 are based on sampling only the Wilderness and Gecko management areas. Numbers for 2006 represent the number of plants counted in a dunes-wide sample of 735 25m x 25m cells. The category seedlings includes young, nonflowering plants.

Year	Number of Adults	Number of Seedlings	Total Number of Plants	Percent Seedlings
1998	5,013	51	5,064	1
1999	942	0	942	0
2000	86	0	0	0
2001	5,186	744	5,930	13
2002	2,143	154	2,297	7
2003	95	15,506	15,601	99
2004	24,426	1,396	25,822	95
2005	188,580	551,225	739,805	26
2006	524	998	1,522	34

Table 6. Precisions attained for 2005 and 2006 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)	
	2005	2006
Mammoth Wash	13%	85%
Wilderness	20%	66%
Gecko	14%	67%
Glamis	22%	84%
Adaptive Management Area	13%	69%
Ogilby	21%	127%
Buttercup	45%	136%
Entire Dunes	8%	37%

Table 7. Number of cells sampled within areas closed by OHVs, the number of those cells with OHV track cover > 0%, and the percent of the sampled cells with OHV track cover > 0%.

Management Area	Number of Cells Sampled Within OHV Closures	Number of Cells with OHV Track Cover > 0%	Percent of Cells Sampled with OHV Track Cover > 0%
Mammoth Wash	46	3	6.5%
Wilderness	100	0	0%
Gecko	49	22	44.9%
Glamis	28	14	50.0%
AMA	199	5	2.5%
Ogilby	20	10	50.0%
Buttercup	0	0	0%
Total	442	54	12.2%

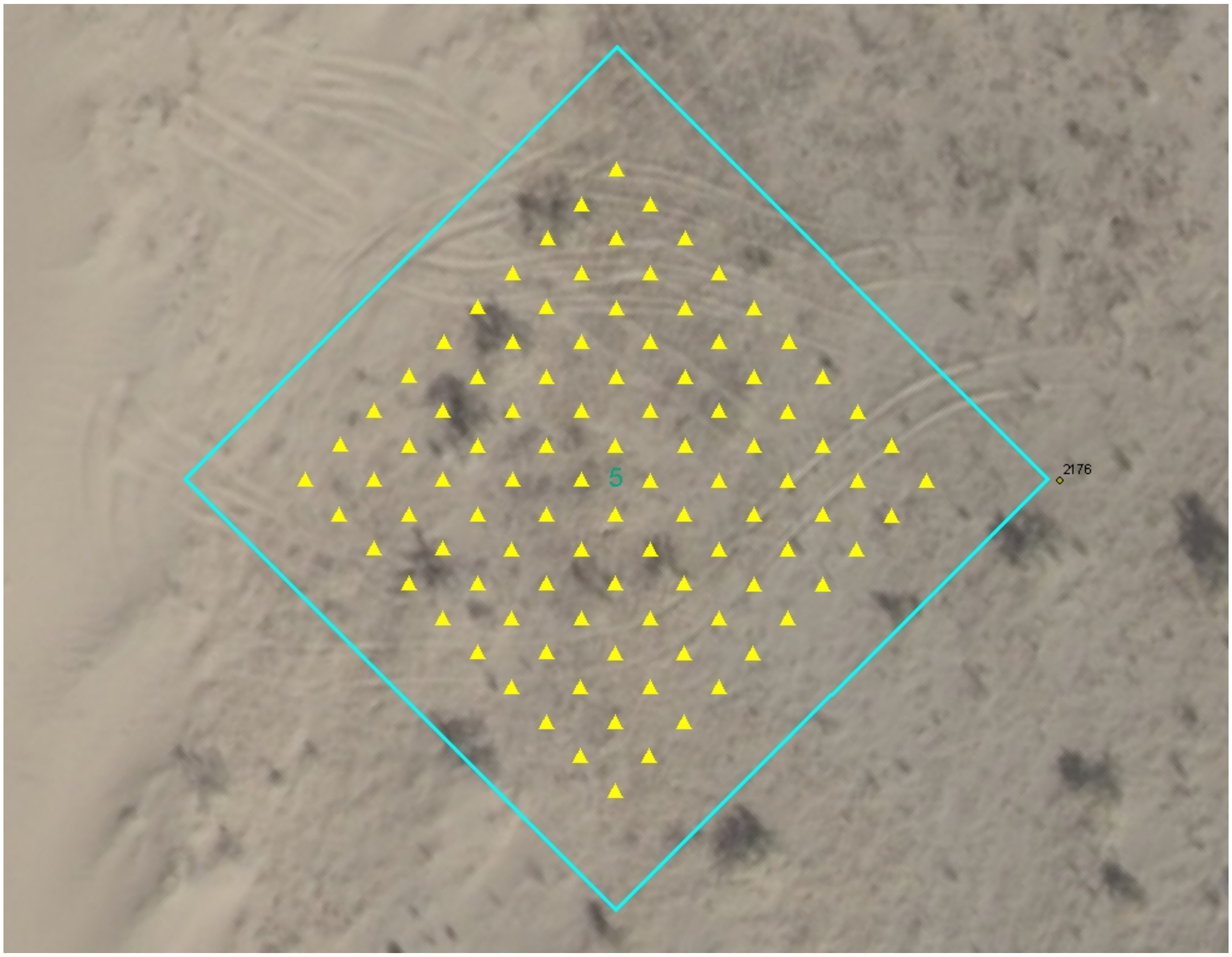


Figure 1. One of the 775 cells sampled for vehicle track cover in 2006. A 100 point grid (yellow triangles) was used to measure cover. The top of each triangle was used as the point. The number of hits on a vehicle track was divided by the total number of points, 100, and multiplied by 100% to obtain the percent cover value assigned to a particular cell. The track cover of this cell, located in the open part of the Mammoth Wash Management Area, was 28%.

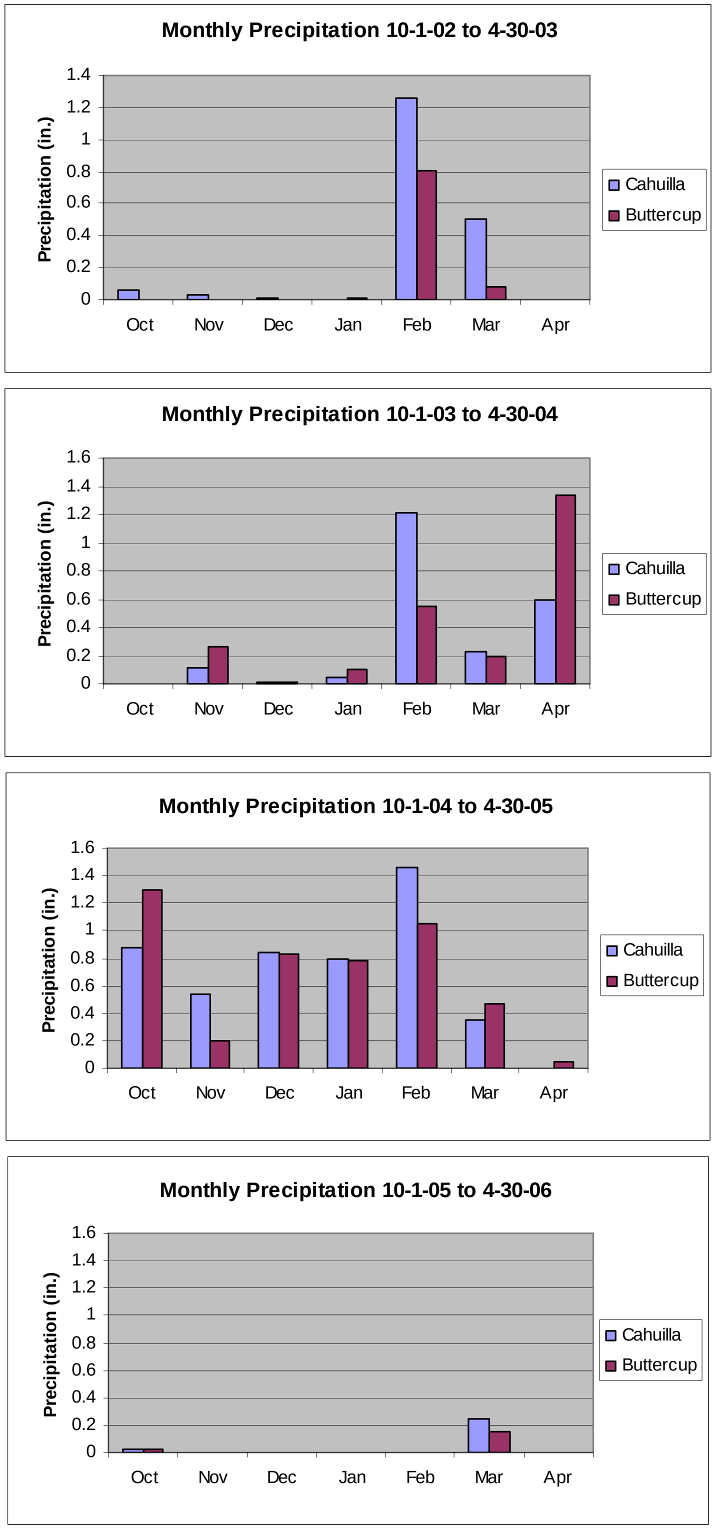


Figure 2. Monthly total precipitation at the two Remote Area Weather Stations in the Algodones Dunes for growing seasons 2002-2003, 2003-2004, 2004-2005, and 2005-2006.

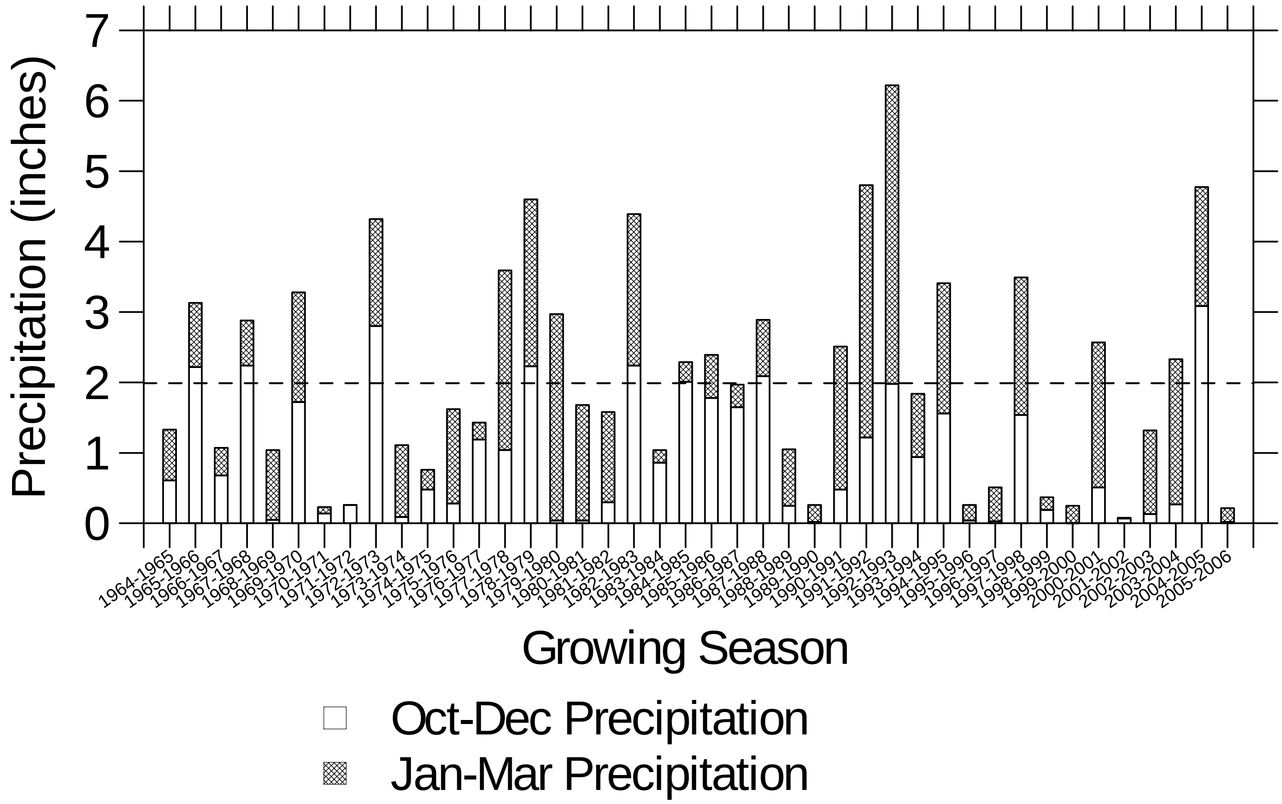


Figure 3. Total growing season (October to March) precipitation for growing seasons 1964-1965 to the present. The bottom part of each bar is the October-December precipitation. The top part of each bar is the January-March precipitation. Precipitation values for growing seasons 1964-1965 to 1999-2000 are the averages of 7 WRCC weather stations in the vicinity of the Dunes. The value for October-December 2000 is from the same source. The values for January-March 2001 and for all subsequent growing seasons are the averages of the precipitation recorded for the two Remote Area Weather Stations in the Dunes. The dashed line is the average growing season precipitation of the 7 WRCC weather stations.

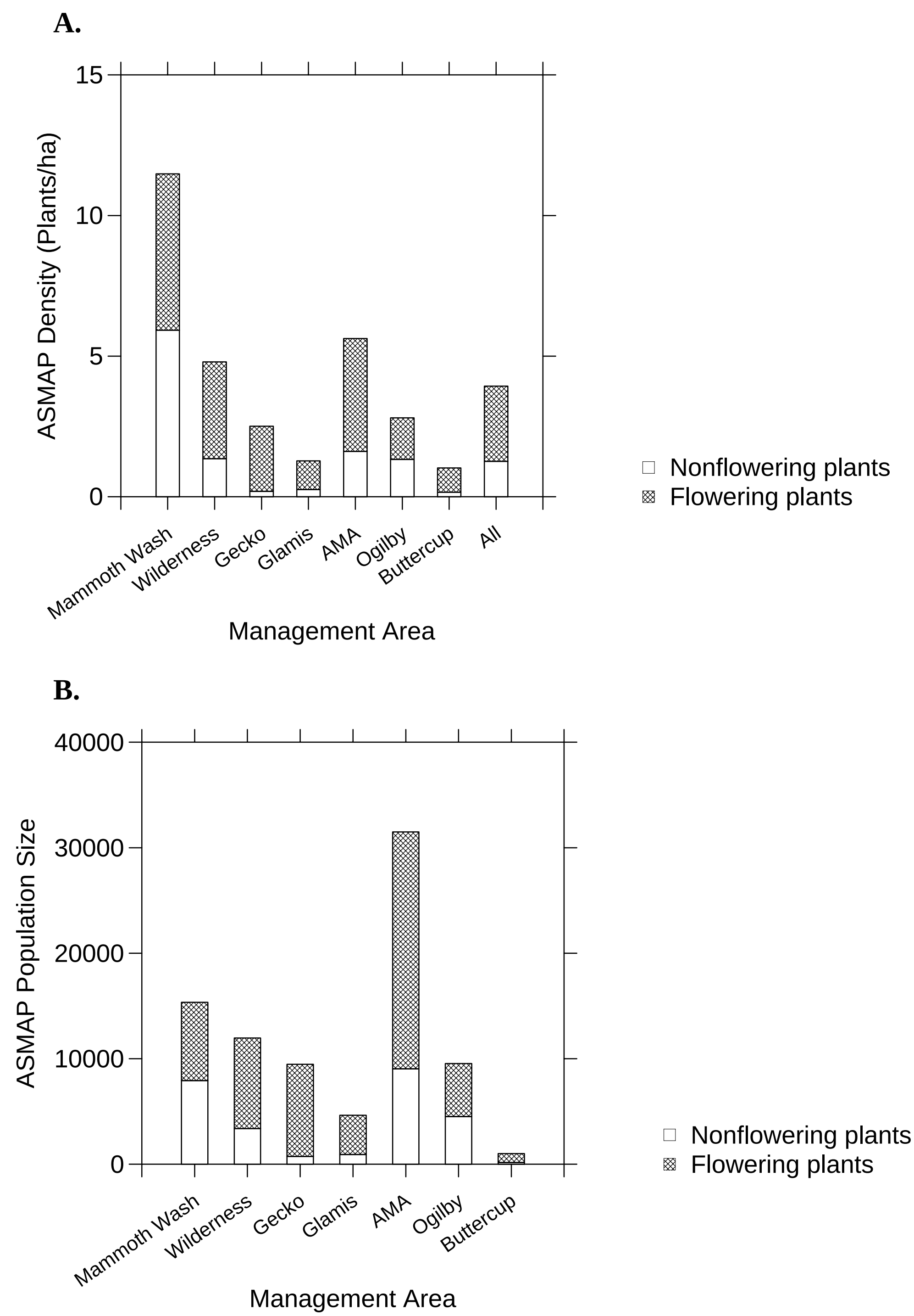
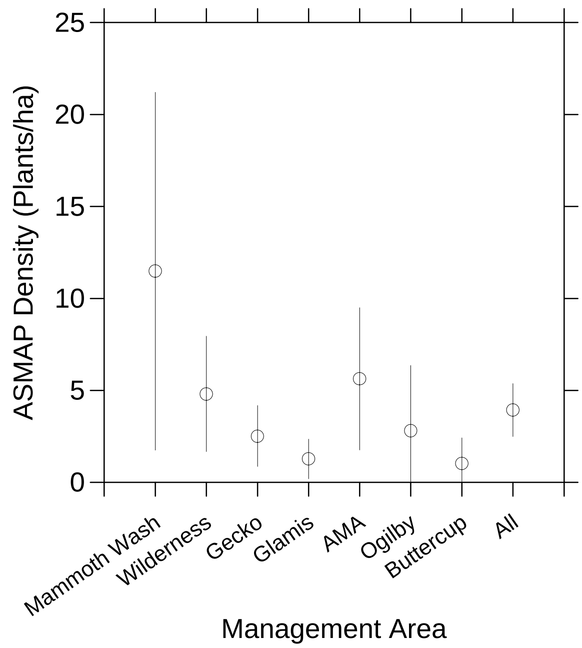


Figure 4. ASMAP estimated density (plants/ha) for each of the management areas and the Dunes as a whole ("all") (A) and estimated population size for each of the management areas in spring 2006 (B).

A.



B.

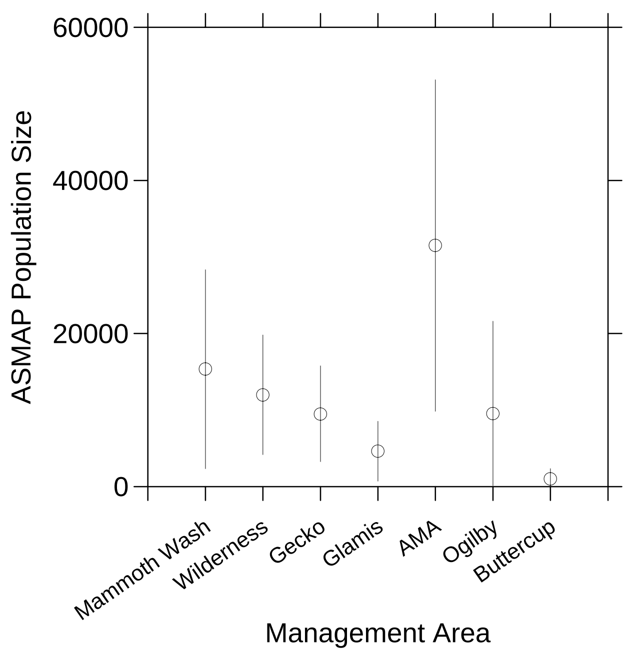
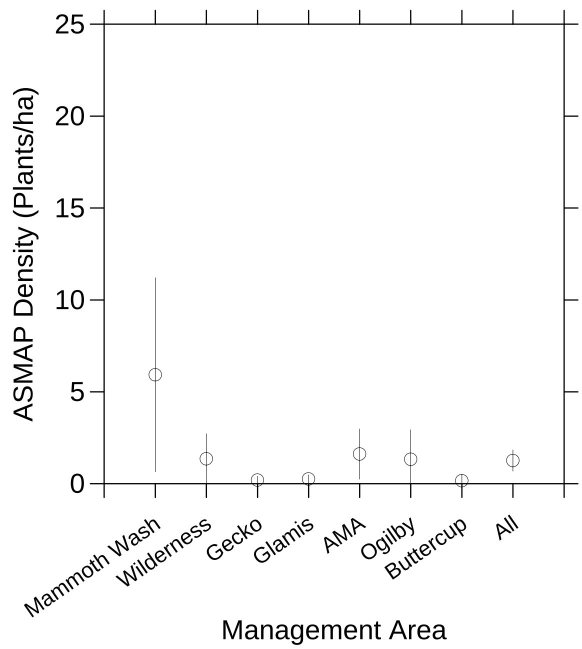


Figure 5. Spring 2006 density (plants/ha) of all ASMAP plants for each of the management areas and the Dunes as a whole (A) and population size of all ASMAP plants for each of the management areas (B). Error bars are 95% confidence intervals.

A.



B.

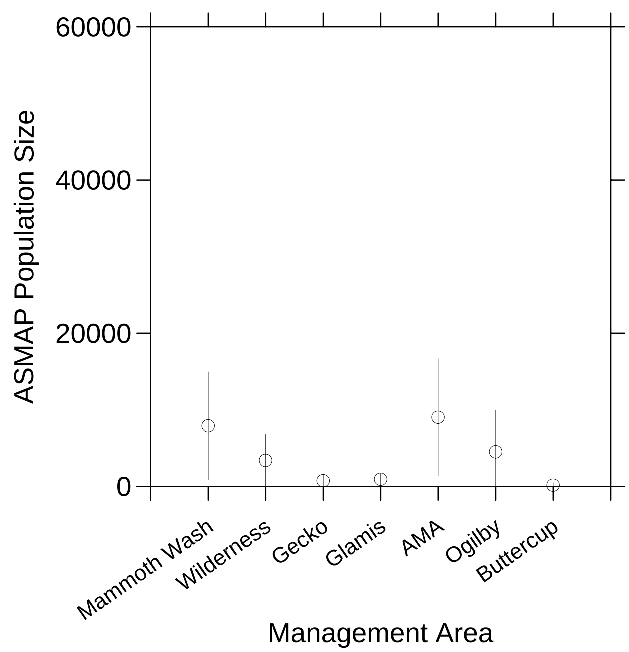
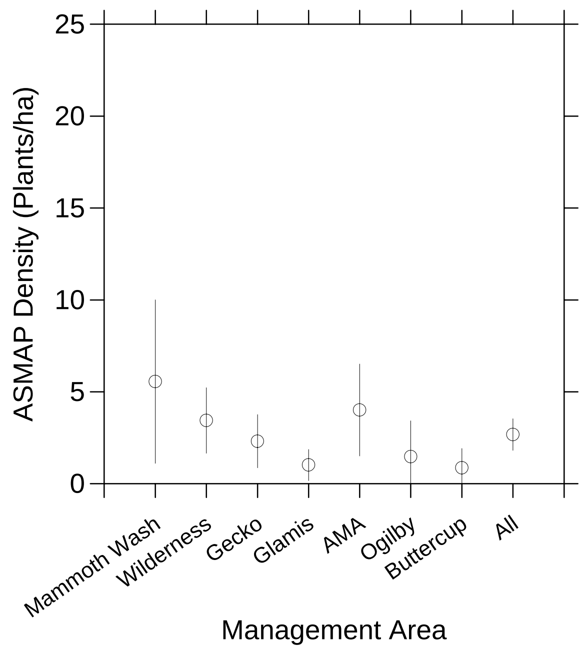


Figure 6. Spring 2006 density (plants/ha) of seedling and young, nonflowering ASMAP plants for each of the management areas and the Dunes as a whole (A) and population size of seedling and young, nonflowering ASMAP plants for each of the management areas (B). Error bars are 95% confidence intervals.

A.



B.

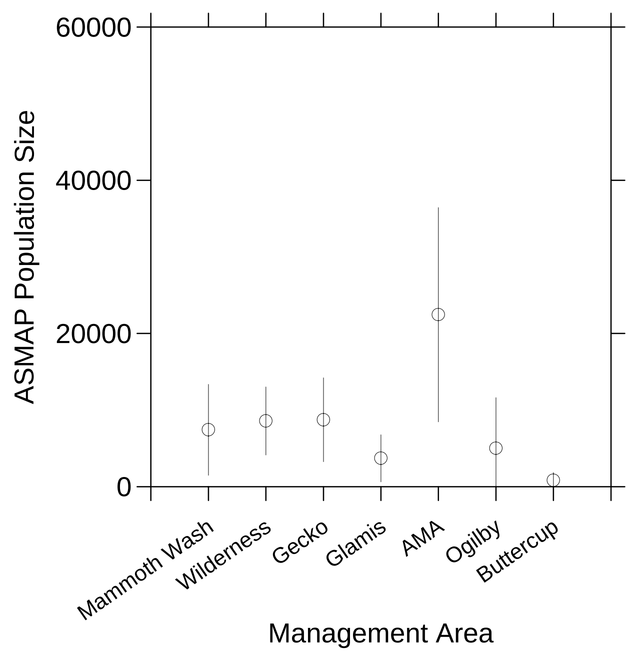
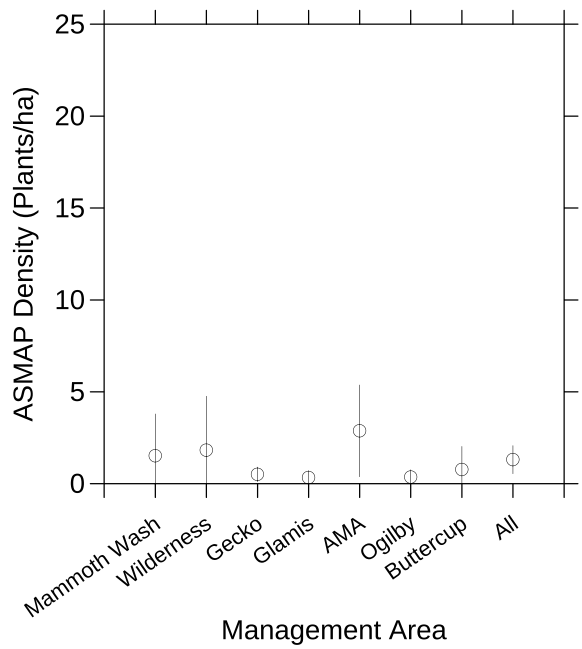


Figure 7. Spring 2006 density (plants/ha) of flowering ASMAP plants for each of the management areas and the Dunes as a whole (A) and population size of flowering ASMAP plants for each of the management areas (B). Error bars are 95% confidence intervals.

A.



B.

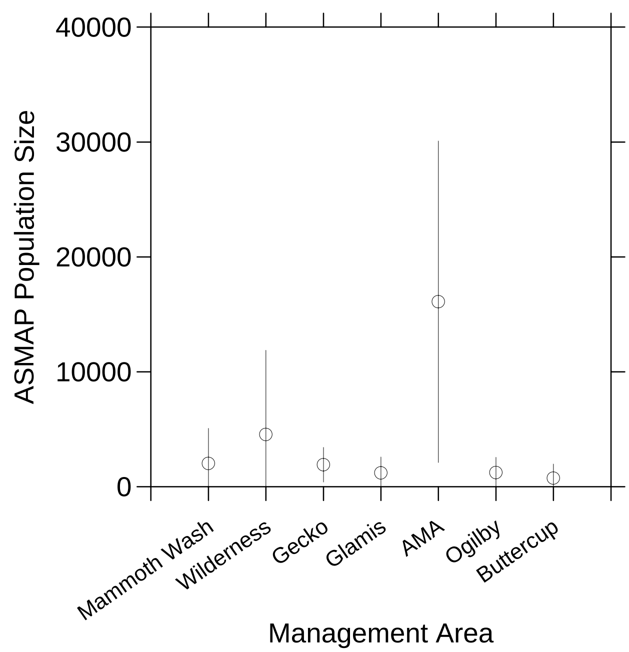
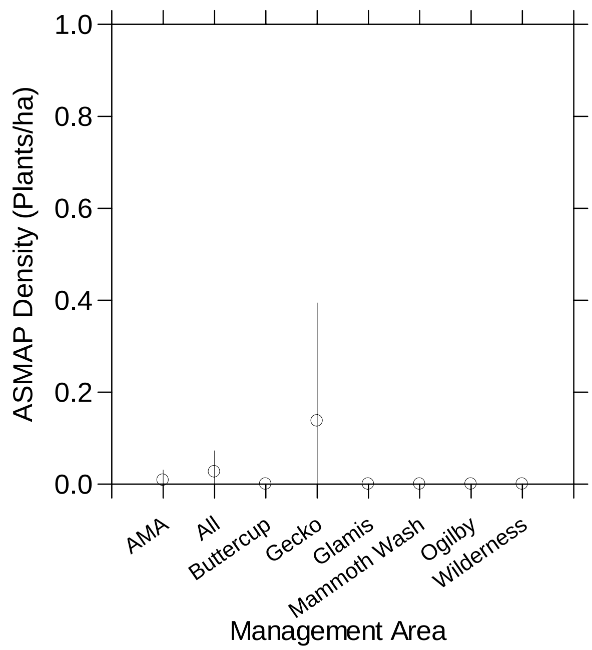


Figure 8. Spring 2006 density (plants/ha) of > 1 year-old ASMAP plants for each of the management areas and the Dunes as a whole (A) and population size of > 1 year-old ASMAP plants for each of the management areas (B). Error bars are 95% confidence intervals.

A.



B.

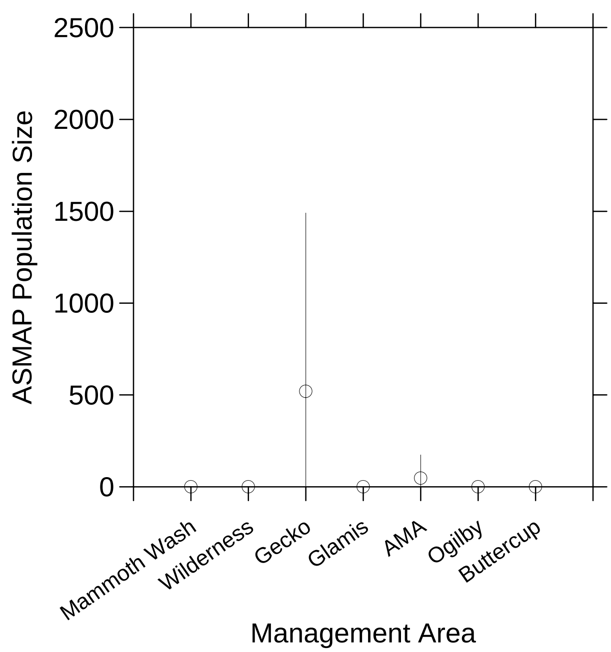
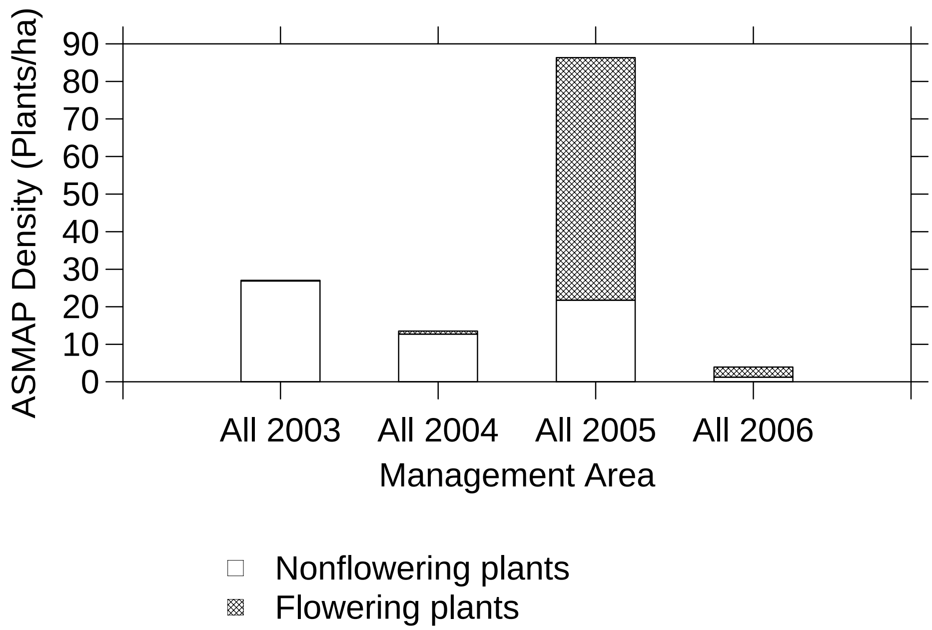


Figure 9. Spring 2006 density (plants/ha) of ASMAP plants showing OHV damage for each of the management areas and the Dunes as a whole (A) and population size ASMAP plants showing OHV damage for each of the management areas (B). Error bars are 95% confidence intervals.

A.



B.

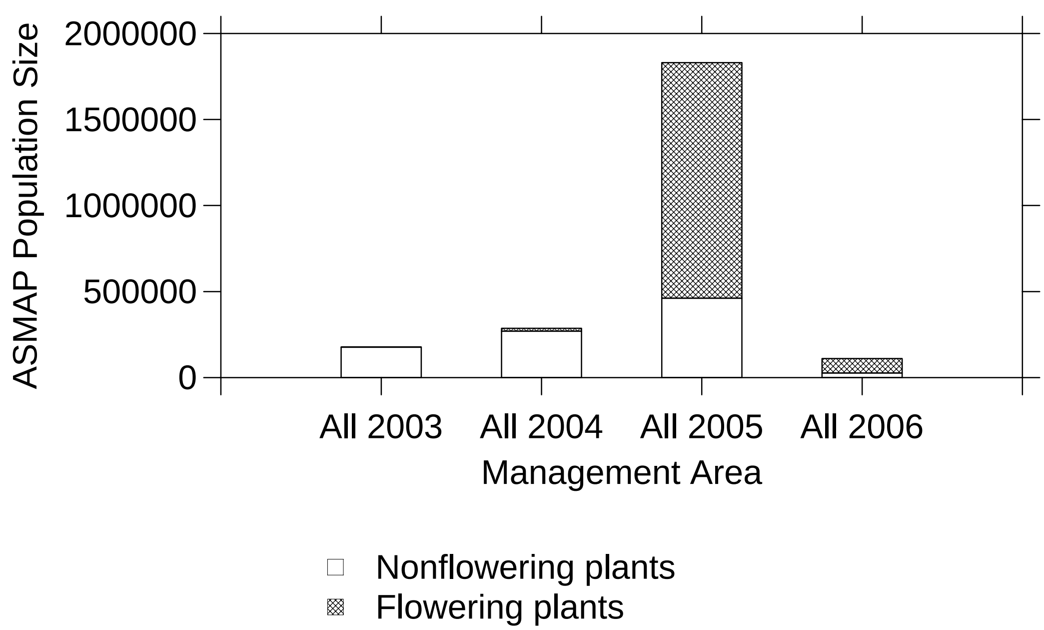


Figure 10. ASMAP density (plants/ha) and stage class distribution in the Algodones Dunes in 2003, 2004, 2005, and 2006 (A) and ASMAP population size and stage class distribution in the Algodones Dunes in 2003, 2004, 2005, and 2006 (B). Values for 2003 are based on monitoring in the Wilderness and Gecko management areas only.

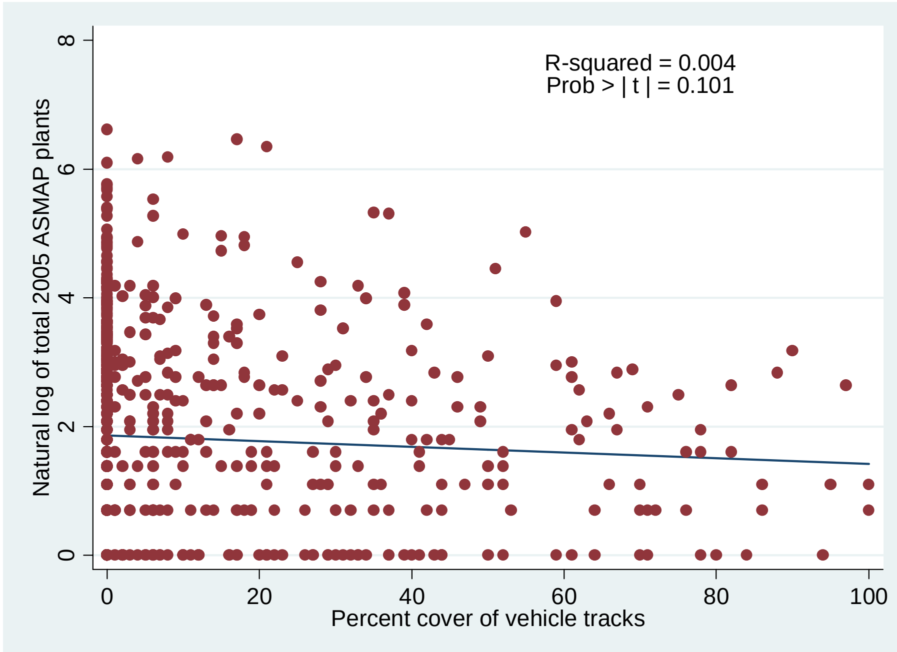


Figure 11. Results of linear regression of the natural log of the total number of ASMAP plants counted in 2005 on the percent cover of vehicle tracks in a stratified random sample of 775 cells from areas open and closed to OHV use in 2005 and 2006.

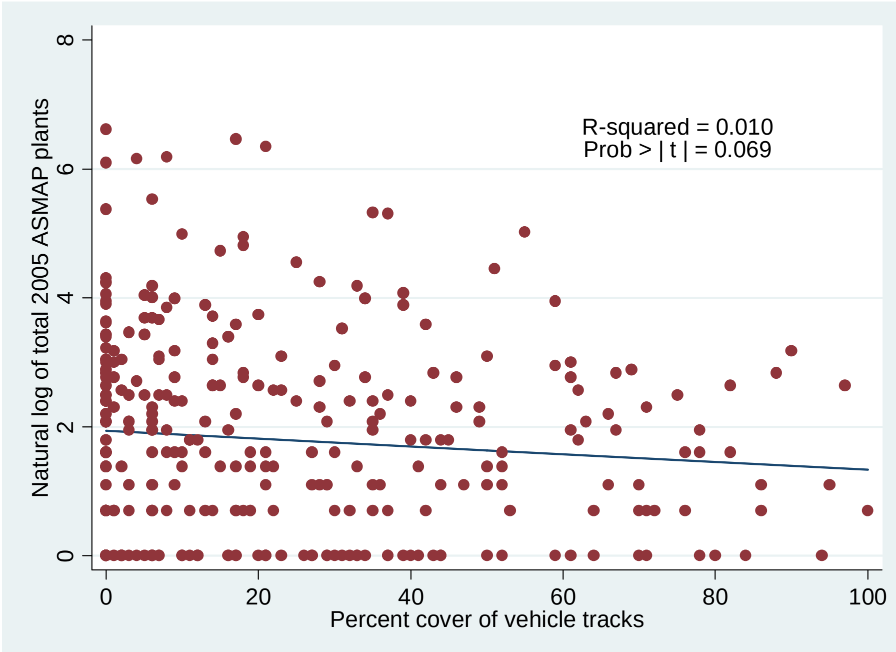


Figure 12. Results of linear regression of the natural log of the total number of ASMAP plants counted in 2005 on the percent cover of vehicle tracks in a stratified random sample of 333 cells from areas open to OHV use in 2005 and 2006.

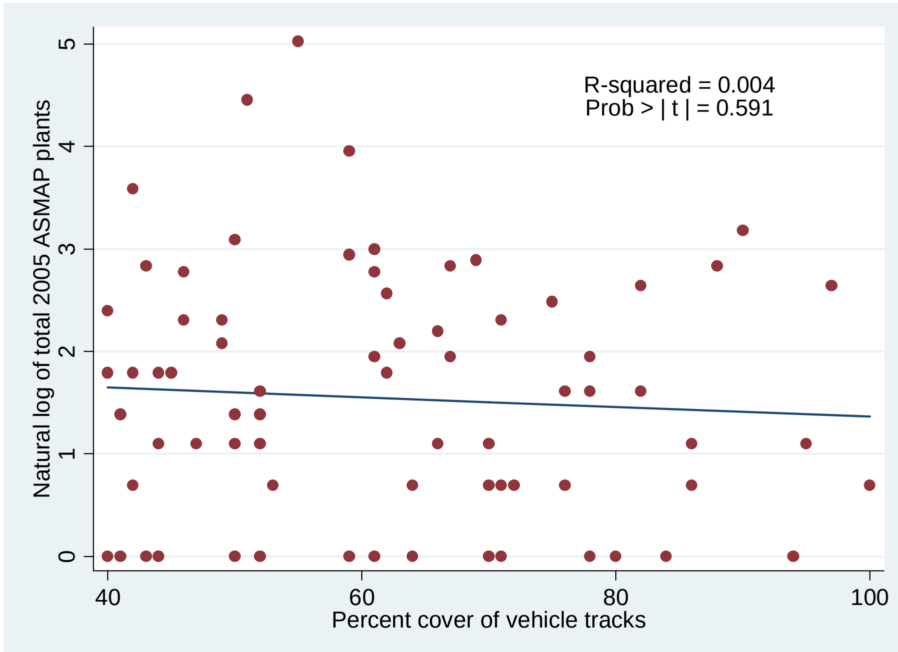
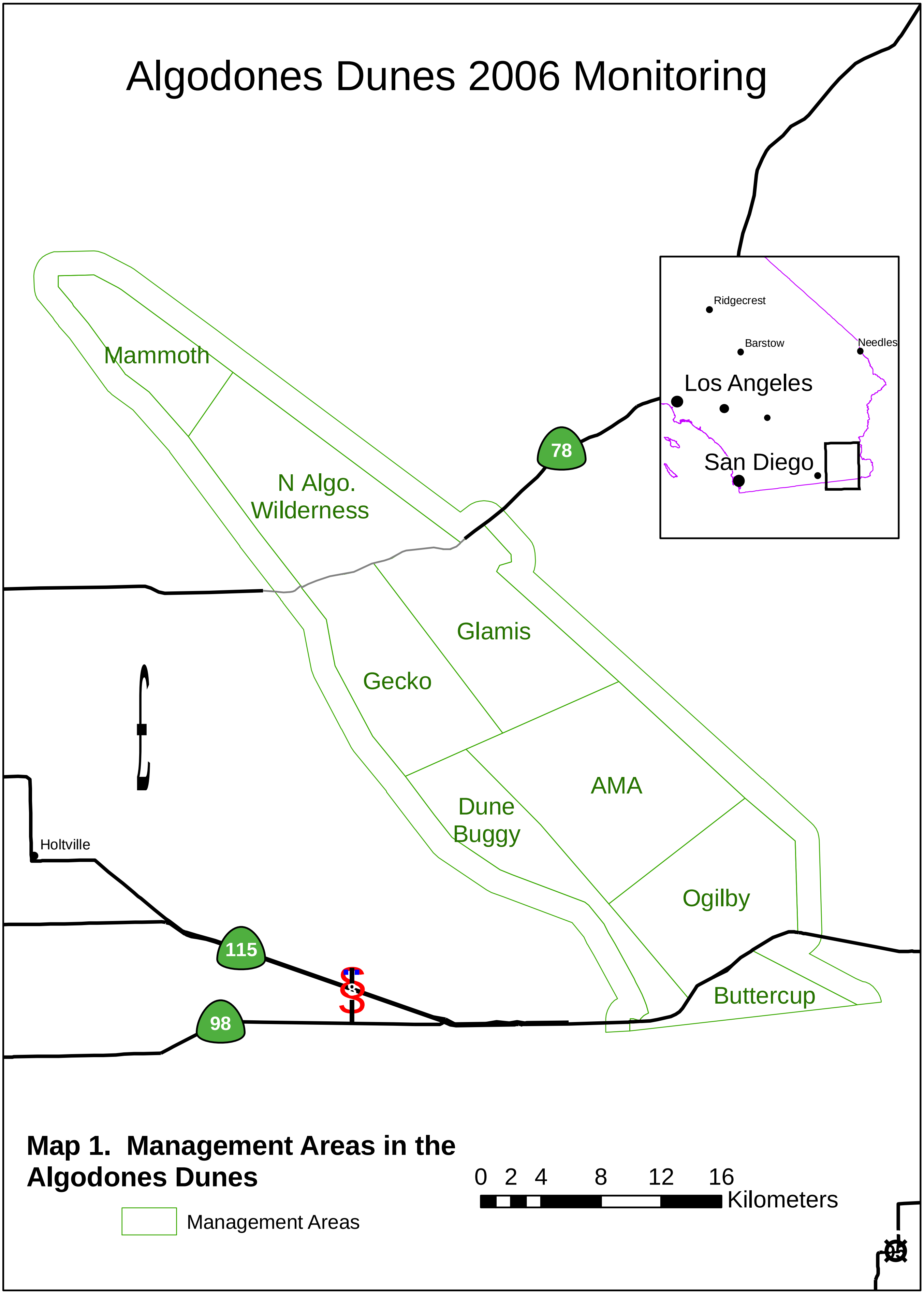


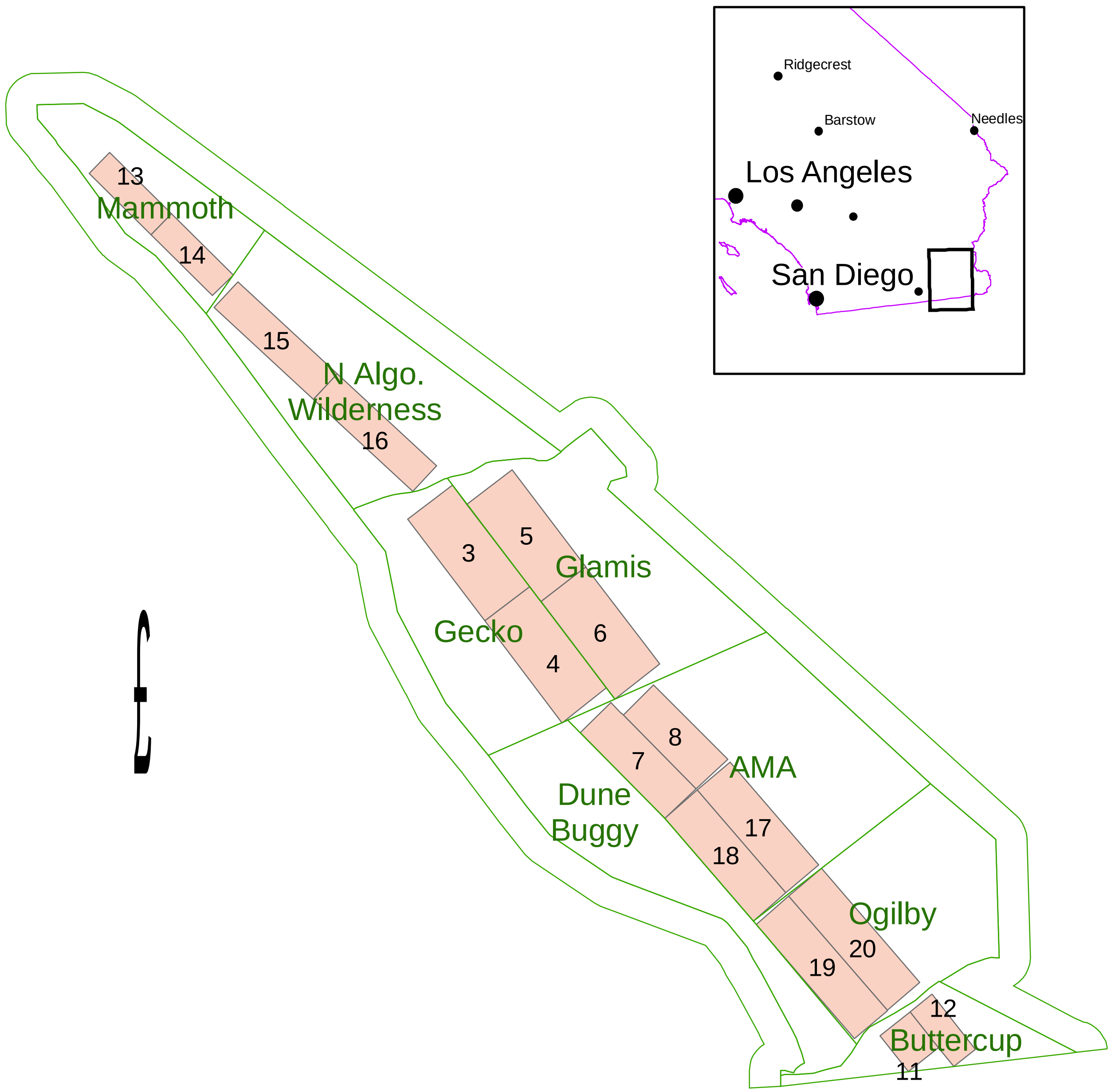
Figure 13. Results of linear regression of the natural log of the total number of ASMAP plants counted in 2005 on the percent cover of vehicle tracks in a stratified random sample of 73 cells from areas open to OHV use in 2005 and 2006. Cells that had vehicle track cover of less than 40% were excluded from analysis.

Algodones Dunes 2006 Monitoring



Map 1. Management Areas in the Algodones Dunes

Algodones Dunes 2006 Monitoring



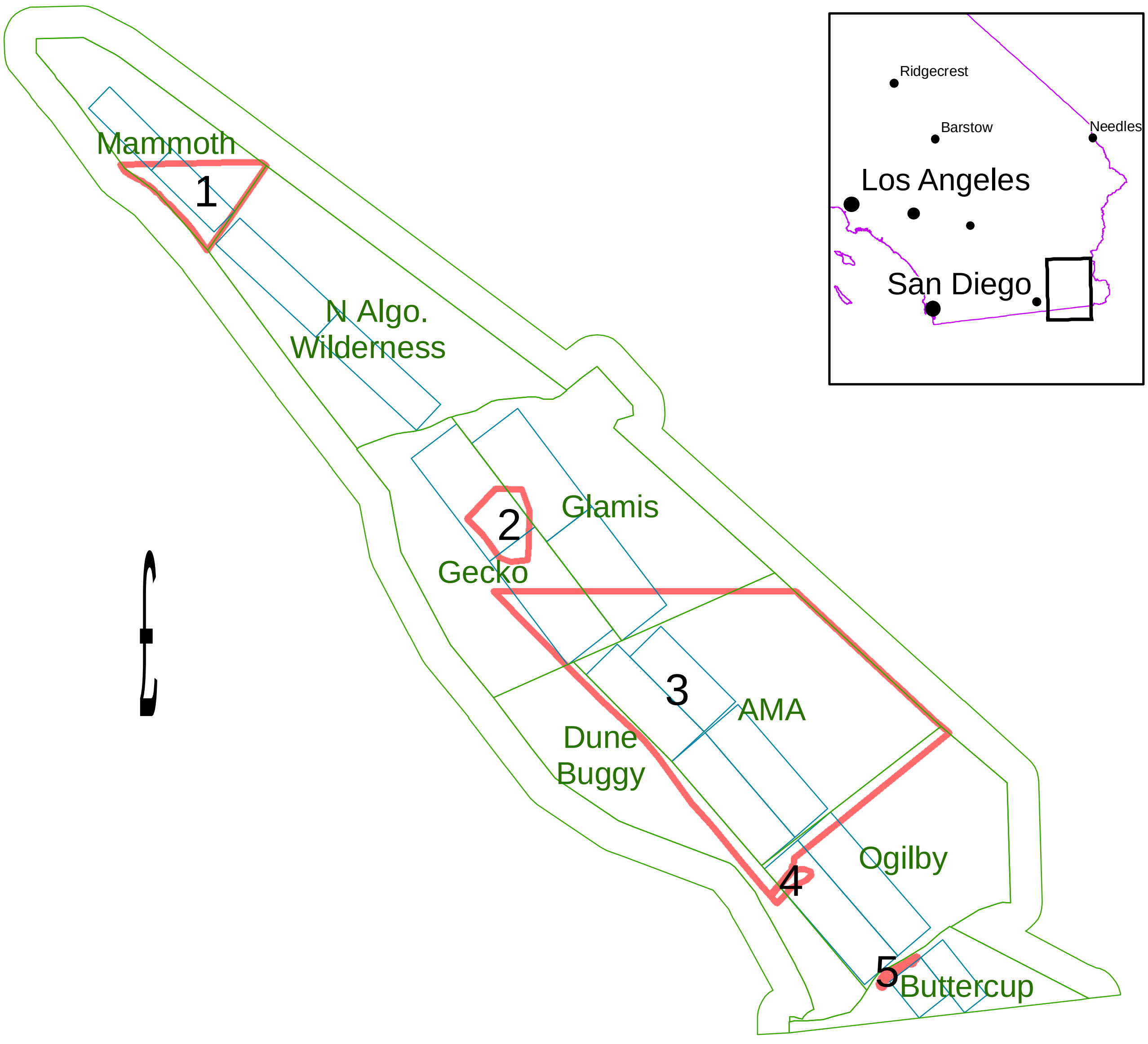
Map 2. 2005 Sampling Areas used for 2006 monitoring

Sampling Areas

Management Areas

0 2 4 8 12 16 Kilometers

Algodones Dunes 2006 Monitoring



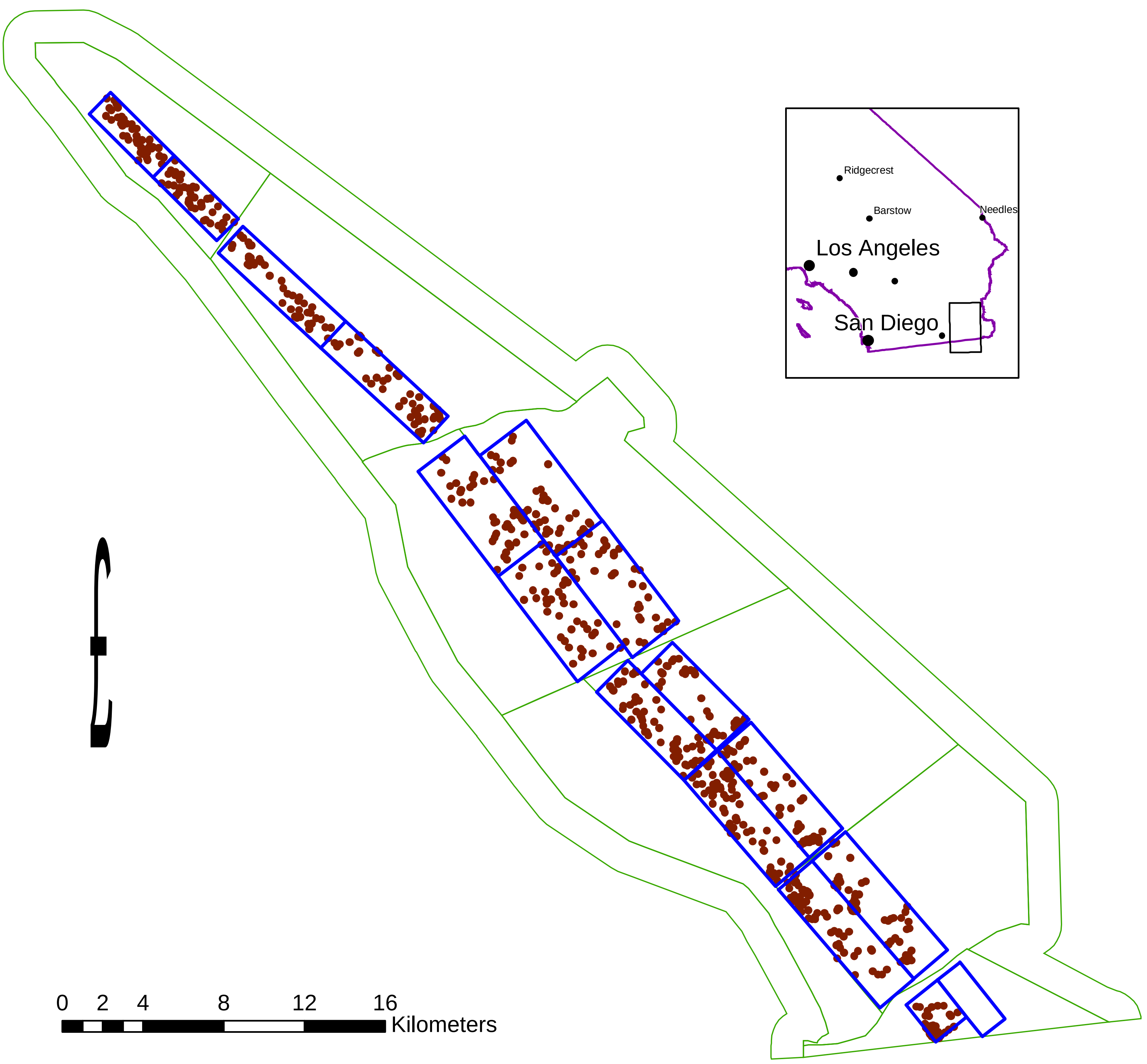
Map 3. Administrative closures in the Algodones Dunes

Administrative Closures

Management Areas

Sampling Areas

Algodones Dunes 2006 Monitoring



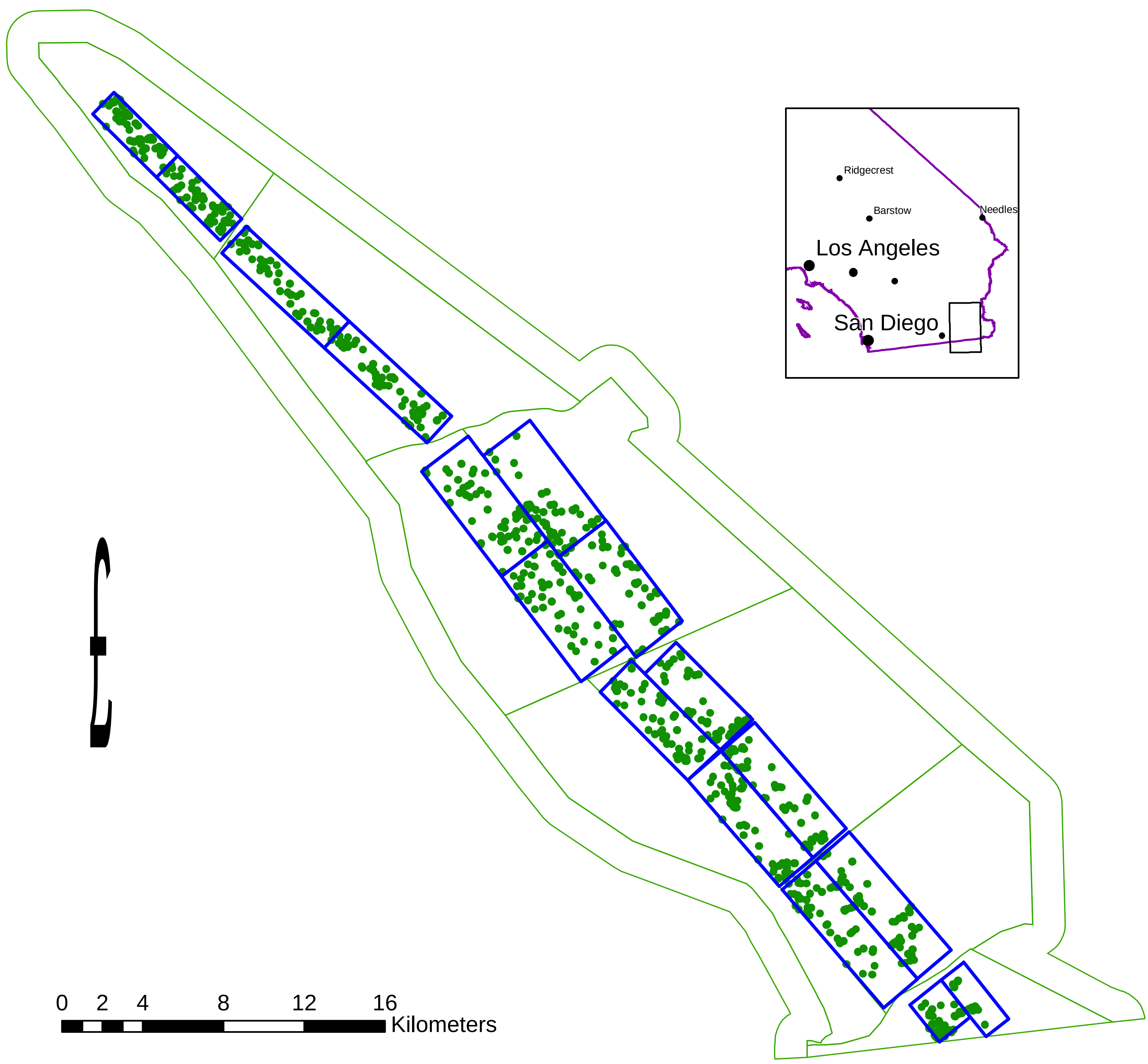
Map 4. Cells Sampled for ASMAP in 2006

Cells sampled in 2006

Management Area Boundaries

Sampling Area Boundaries

Algodones Dunes 2006 Monitoring



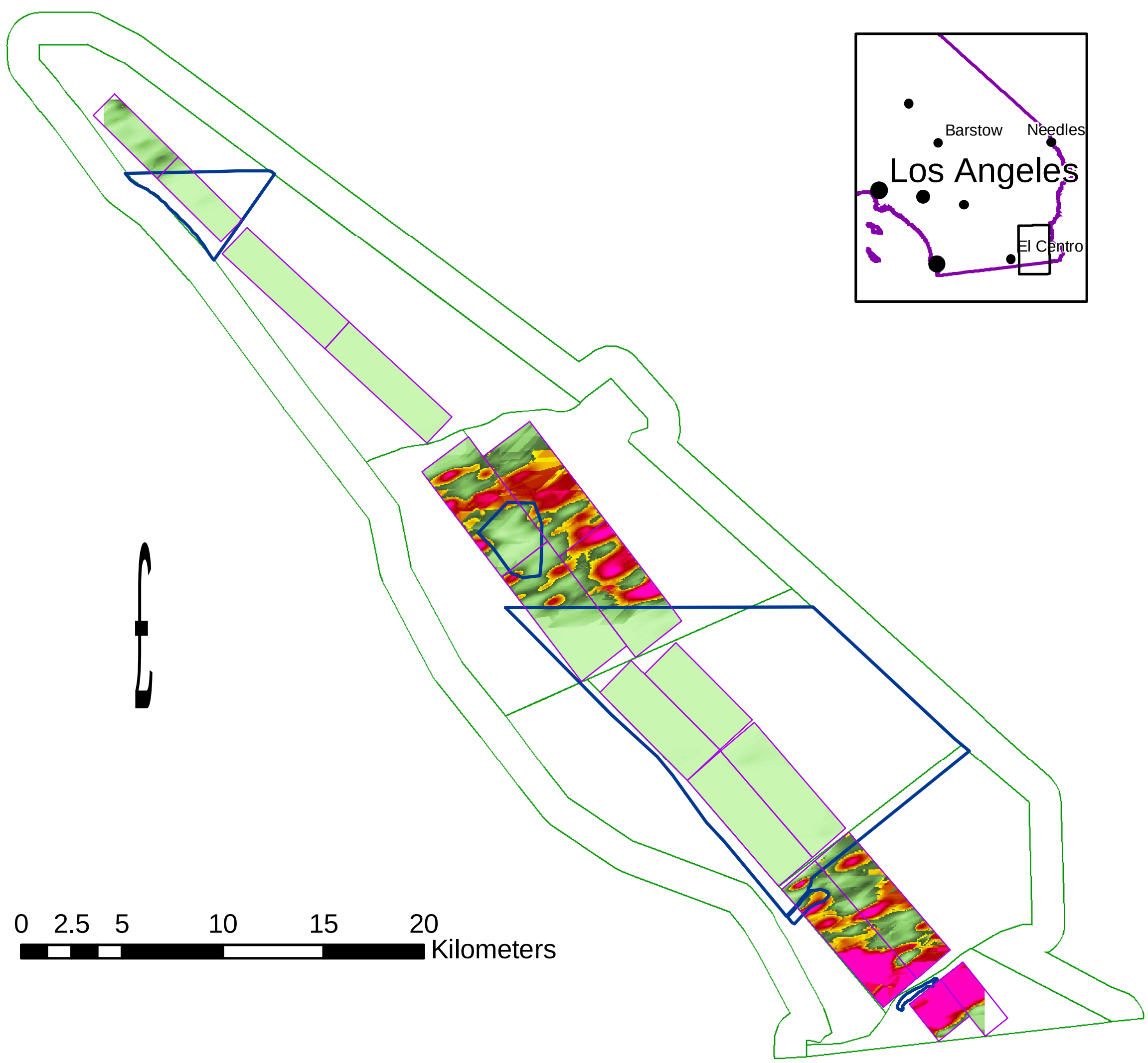
Map 5. Cells Sampled for Vehicle Track Cover on Aerial Photography Acquired on Presidents' Day Weekend 2006.

Sampling Area Boundaries

Management Area Boundaries

Cells sampled for track cover

Algodones Dunes Vehicle Track Cover
Presidents' Day Weekend 2006



Map 6. Predicted OHV track cover from ordinary kriging of 775 cell values.

Vehicle track cover

High : 93%

Low : 0%

Management Area Boundaries

Sampling Area Boundaries

Administrative Closures