Monitoring of Peirson's Milk-vetch in the Imperial Sand Dunes Recreation Area

Bureau of Land Management
El Centro Field Office, 2017

Cover photograph of Peirson's milk-vetch
(*Astragalus magdalenae* var. *peirsonii*)
by Chris Knauf

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Preface

The author of this report is John Willoughby, contract botanist, Bureau of Land Management (BLM), California State Office. This report documents 2017 monitoring of Peirson's milk-vetch (PMV) in the Imperial Sand Dunes Recreation Area, as required by the Imperial Sand Dunes Recreation Area Management Plan.

The monitoring study was designed by John Willoughby, Tony McKinney of the Carlsbad Fish and Wildlife Office of the U.S. Fish and Wildlife Service (USFWS), and Andrew Trouette of the BLM El Centro Field Office. Tony used data from a 2005 dunes-wide survey of Peirson's milk-vetch to select macroplots for monitoring and created waypoints that were downloaded into global positioning system devices for navigating to each macroplot and recording data. This report documents the fourth year of the monitoring. Although the same macroplots were monitored in 2017, the methods used to record data were amended in 2017 by Camden Bruner of the BLM El Centro Field Office and Jeffrey Sahagun of the BLM California Desert District. The monitoring conducted in 2014 and 2015 is documented in Willoughby (2015), and the 2016 monitoring is documented in Willoughby (2017).

The 2017 monitoring was conducted by:

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Asdrubal Estrada, Lead PMV Closure Park Ranger, BLM El Centro Field Office

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Executive Summary

In spring 2017, the Bureau of Land Management (BLM) monitored the abundance of Peirson's milk-vetch (*Astragalus magdalenae* var. *peirsonii*, hereafter referred to as PMV) in the Imperial Sand Dunes Recreation Area, located in southeastern Imperial County, California. PMV is a Federally-listed threatened species and a State-listed endangered species.

Annual monitoring of PMV began in late winter of 2014 and continued in late winter and early spring of 2015 (Willoughby 2015) and late winter 2016 (Willoughby 2017). The 2017 monitoring reported on here represents the fourth year of monitoring.

The Imperial Sand Dunes Recreation Area Management Plan (ISDRAMP) prescribes two levels of monitoring for PMV, a full-scale approach when October-December precipitation at the Dunes is greater than 1.82 inches and a less-intensive approach when precipitation during the October-December period is less than 1.82 inches (see Introduction for how this 1.82 inch threshold was derived). Nineteen macroplots, each 50m x 500m in size, were permanently established in areas representing the full range of Peirson's milk-vetch habitat in the Dunes, including areas both open and closed to off-highway vehicles (OHVs). Six of these macroplots are to be monitored in years in which the October-December precipitation is less than 1.82 inches, and all 19 macroplots are to be monitored in years in which the precipitation during that period equals or exceeds 1.82 inches.

Because the October-December precipitation was less than 1.82 inches in 2017, the monitoring effort was directed toward six macroplots. An additional macroplot, Macroplot 19, was also monitored in 2017 as part of a training exercise to test some new methods for navigation, data recording, and delineation of macroplot boundaries.

For the first time in the four years of the current PMV monitoring program, growing season rainfall was above average, both for the growing season as a whole and for both halves (October-December and January-March). PMV plants responded positively to this increased rainfall: a total of 18,826 plants were counted in 2017 across the seven macroplots monitored. Not counting Macroplot 19, there were 17,480 total plants in 2017, compared to 6,047 in 2016, 2,719 in 2015, and 2,307 in 2014.

As in previous years, Macroplot 13 supported the largest number of plants with 77% of the plants observed. Macroplot 10 was the next most populated macroplot, accounting for almost 9% of the total. Macroplot 15 (7%), Macroplot 6 (4%), Macroplot 16 (2%), and Macroplot 8 (1%) account for the rest of the plants. Based on the 2005 sampling, there is a north-south gradient in terms of number of plants, with the southern part of the Dunes supporting more plants than the northern part. Thus, the larger number of plants observed in macroplots 13

compared to the number observed in macroplots 6 and 8 would be as expected given that the former macroplot is in the southern part of the Dunes and the latter macroplots are in the northern part. Macroplot 10 is closer to Macroplot 13, so the fact that its numbers are higher than macroplots 6 and 8 is also to be expected. Perhaps most surprising is that Macroplot 16, also in the southern dunes, supported only 2% of the plants observed in 2017. This apparently is not related to a north-south rainfall gradient in 2017 because Macroplot 19, in the extreme southern part of the dunes, contributes 7% of the total number of plants when all seven macroplots are considered.

Almost all (99%) of the plants counted in 2017 were seedlings and young, non-flowering plants. The plants observed appeared to represent two or perhaps three cohorts. The first cohort likely germinated in response to late December rains. These plants were the largest observed (between 10 and 15 inches tall), and a few of these were flowering. Another cohort may have germinated in response to rather light rains in January and another cohort certainly germinated after rather substantial mid-February rains. These plants were still seedlings and small juveniles at the time of the early April monitoring. Some of the plants from the late December cohort may have persisted to the flowering stage subsequent to monitoring, but it is unlikely that the February cohort flowered in 2017.

The stage-class distribution of plants in 2017 is similar to that observed in the previous three years of monitoring, with almost all of the plants observed being in the seedling and non-flowering category. The disproportionate number of non-flowering plants in 2017 is likely the result of uneven distribution of rainfall through the growing season: despite the fact that the first half (October-December) of the growing season had above average precipitation, most of this rain fell in late December, leaving insufficient time for plants to flower by the time of monitoring. Contrast this to the stage-class distribution in 2005 when 75% of the plants were flowering at the time of monitoring. The 2004-2005 growing season experienced rainfall that was both much higher than average and well distributed throughout both the early and late halves of the growing season.

Only 12 out of 18,226 plants (0.06%) observed in 2017 were greater than one year old. This is likely reflective of the below-average growing season precipitation in the years 2014-2016. Given the fact that there was no precipitation at all in both February and March 2016, it is quite likely that the seedlings observed in late February and early March 2016 did not survive to flower in 2016, let alone survive summer 2016.

Although the 2017 monitoring did not show any significant problems with direct impacts from OHV use, the presence of OHV tracks in macroplots 10 and 19 (within Peirson's milk-vetch

critical habitat) may point to the need for additional signage and/or increased ranger patrols along the critical habitat borders.

Introduction

In spring 2017, the Bureau of Land Management (BLM) monitored the abundance of Peirson's milk-vetch (*Astragalus magdalenae* var. *peirsonii*, hereafter referred to as PMV) in the Imperial Sand Dunes Recreation Area, located in southeastern Imperial County, California. PMV is a Federally-listed threatened species and a State-listed endangered species.

The Imperial Sand Dunes Recreation Area Management Plan (ISDRAMP) was approved in June 2013 (BLM 2013). The ISDRAMP closed PMV critical habitat, designated by the U.S. Fish and Wildlife Service (USFWS 2008), to off-highway vehicles (OHVs). It also called for the lifting of interim OHV closures in effect since November 2000 pursuant to a series of lawsuits filed against BLM. These interim OHV closures were lifted in fall 2014 following a court decision earlier in 2014 (BLM 2014).

Annual monitoring of PMV began in late winter of 2014. Previous monitoring results are documented in Willoughby (2015, for the 2014 and 2015 efforts) and Willoughby (2017, for the 2016 effort). The 2016 monitoring reported on here represents the fourth year of monitoring.

Appendix D of the ISDRAMP prescribes two levels of monitoring for PMV, a full-scale approach when October-December precipitation at the Dunes is greater than 1.82 inches and a less-intense approach when precipitation during the October-December period is less than 1.82 inches. The 1.82 threshold is the average October-December precipitation between 1964 and 2010 (0.89 inches) plus one standard deviation (0.93 inches; see Figure 1). A spring following this level of October-December precipitation is one in which significant PMV germination, growth, and seed production can be expected (Phillips and Kennedy 2003 and 2006; Willoughby 2001 and 2004). As an example, spring of 2005 was a banner year for PMV plants, as shown by BLM's 2005 monitoring program (Willoughby 2005b). The October-December precipitation for 2004 was well above the 1.82 inch threshold (Figure 1).

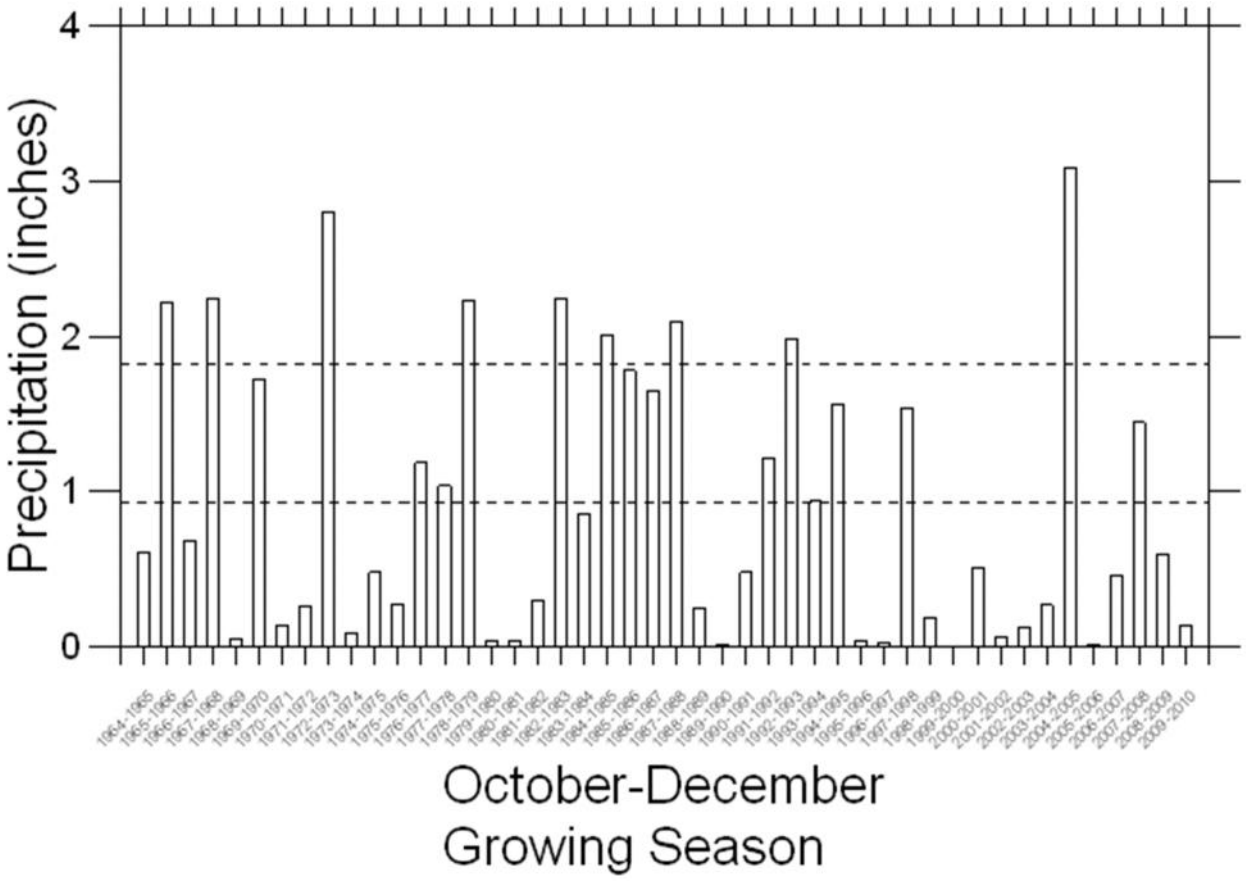

Figure 1. October to December precipitation from growing seasons 1964-1965 to 2009-2010. The full growing season is defined as October 1 to March 30. Thus, the October-December period is the first half of the growing season. Precipitation values for growing seasons 1964-1965 to 2000-2001 are the averages of seven WRCC weather stations in the vicinity of the Imperial Sand Dunes. The values for growing seasons 2001-2002 to 2009-2010 are the averages of the precipitation recorded for the two Remote Area Weather Stations in the Imperial Sand Dunes (these stations were installed in November 2000). The bottom dashed line is the average October-December growing season precipitation of the 7 WRCC weather stations (0.93 inches). The top dashed line is 1 standard deviation above the average (standard deviation = 0.89 inches). Growing seasons with October-December precipitation higher than the standard deviation line would be expected to be banner years for Peirson's milk-vetch. Monitoring during the spring following the 2004-2005 growing season (Willoughby 2005b) appears to bear this out.

Methods

Monitoring. In 2014 nineteen permanent macroplots were established in areas representative of good PMV habitat in the Imperial Sand Dunes. Macroplots are 50m x 500m in size and are oriented southwest to northeast. The macroplots are divided into forty 25m x25m cells (Figure 2).

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
40	39	38	37	36	35	34	33	32	31	30	29	28	27	26	25	24	23	22	21

Figure 2. 50m x 500m macroplot showing division of macroplot into forty 25m x 25m cells for data recording purposes. Cells are read in the order they are numbered, from Cell 1 to Cell 40.

A cell size of 25m x 25m was chosen to mimic the cell sizes used in the 2003-2007 sampling of Peirson's milk-vetch (Willoughby 2004b, 2005a, 2005b, 2006, 2007). In those studies long, belt transects 25m wide and between 2.35 and 7.73 km long were employed to estimate the population size of PMV in each year. Counts of variables were recorded in 25m segments along each belt transect, resulting in a dataset consisting of more than 339,000 cells in 2005, of which more than 26,116 supported one or more PMV plants. The 2005 data represents both the richest data set (in terms of number of cells read) and the best estimate to date of the abundance and distribution of PMV in the Imperial Sand Dunes (FWS 2008; Willoughby 2006).

The 2005 monitoring project divided the dunes into 16 sampling areas, each of which was sampled using a systematic random sampling scheme (Map 1).[1] Ten of these sampling areas were selected for monitoring in 2014 and beyond based on the number of plants found in the 2005 survey. The chosen sampling areas run the full extent of the dunes from northwest to southeast, but include only the westernmost sampling areas in areas of the dunes south of the North Algodones Dunes Wilderness Area. This is because most PMV plants occupy these westernmost sampling areas, which is also the reason that most of the critical habitat is concentrated in these westernmost sampling areas (Map 1).

Table 1 lists the general locations, number of macroplots, and the criteria used to distribute the nineteen permanent PMV macroplots among the 10 sampling areas in the Imperial Sand Dunes. In years with October-December precipitation above 1.82 inches, all 19 of these macroplots will be monitored.

[1] Note that the numbering system for the 16 sampling areas used in 2005 is missing the numbers 1, 2, 9, and 10. Sampling areas with those numbers were sampled in 2004 and proved to be too variable, so they were divided into smaller sampling areas for the 2015 sampling. New numbers were assigned to these smaller sampling areas.

Table 1. Distribution of 19 Peirson's milk-vetch monitoring macroplots in the Imperial Sand Dunes. The table lists sampling areas from north to south (see Map 1).

Sampling Area	Number of Macroplots	Criteria
13	1	One macroplot in the Mammoth Wash area of the Dunes in critical habitat north of the area that was closed between 2000 and 2013.
14	1	One macroplot in the Mammoth Wash area of the Dunes in critical habitat inside the area closed between 2000 and 2013.
15	1	One macroplot in critical habitat in the northern part of the Wilderness.
16	1	One macroplot in critical habitat in the southern part of the Wilderness.
3	2	One macroplot outside the former closure area and one inside. This is outside of critical habitat but in an area that supported plants in 2005.
4	2	One macroplot outside both former closure areas and one inside the former large central closure. This is outside of critical habitat but in an area that supported plants in 2005.
7	3	As all of this sampling area was closed between 2000 and 2013 the macroplots will be evenly distributed in critical habitat from north to south.
18	3	As all of this sampling area was closed between 2000 and 2013 the macroplots will be evenly distributed in critical habitat from north to south.
19	4	Three macroplots evenly distributed between the north and south parts of the sampling area in the critical habitat area north of the former OHV corridor to Patton Valley (with one just north of the corridor) and one macroplot in the critical habitat area south of the former corridor.
11	1	One macroplot in the critical habitat area in this sampling area.
Total	**19**	

In years with October-December precipitation less than 1.82 inches, six of the 19 macroplots will be monitored. Table 2 lists the general locations, number of macroplots, and the criteria used to distribute these six PMV macroplots among the 10 sampling areas in the Imperial Sand Dunes.

Table 2. Monitoring macroplots to be censused in low rainfall years.

Sampling Area	Number of Macroplots	Criteria
13	0	
14	0	
15	0	
16	0	
3	1	The macroplot inside the former closure area would be monitored. The reason for this is that the area closed was chosen based on it supporting more plants in the 1998 study (Willoughby 1998).
4	1	The macroplot inside the former central closure area would be monitored. The reason for this is that the area closed was chosen based on it supporting more plants in the 1998 study.
7	1	The middle of the three macroplots in this sampling area will be censused.
18	1	The middle of the three macroplots in this sampling area will be censused.
19	2	Because of potential concerns related to the vehicle corridor to Patton Valley (closed in summer 2014) near the boundary between critical habitat subunits 3A and 3B, the macroplots just north and south of the former corridor will be censused.
11	0	
Total	**6**	

Based on these general criteria, Tony McKinney, GIS expert with the Carlsbad Fish and Wildlife Office of the Fish and Wildlife Service, used the 2005 monitoring data to create specific locations for each of the 19 macroplots (Map 2). See Willoughby (2015) for the methods Tony employed to determine specific macroplot locations.

Table 3 lists the 19 macroplots and shows their location relative to the 2005 sampling areas. Map 2 plots their locations in the Dunes.

Table 3. Macroplots and their positions in the Imperial Sand Dunes. X's show the macroplots to be monitored according to the October-December precipitation threshold.

Macroplot	Sampling Area	October-December Precipitation		Location
		< 1.82 inches	> 1.82 inches	
1	13		X	In critical habitat
2	14		X	In critical habitat
3	15		X	In North Algodones Wilderness Area
4	16		X	In North Algodones Wilderness Area
5	3		X	In area never closed to OHV use
6	3	X	X	In area closed to OHV use 2000-2014
7	4		X	In area never closed to OHV use
8	4	X	X	In area closed to OHV use 2000-2014
9	7		X	In critical habitat in northern part of sampling area
10	7	X	X	In critical habitat in middle part of sampling area
11	7		X	In critical habitat in southern part of sampling area
12	18		X	In critical habitat in northern part of sampling area
13	18	X	X	In critical habitat in middle part of sampling area
14	18		X	In critical habitat in southern part of sampling area
15	19	X	X	In critical habitat just north of former vehicle corridor to Patton Valley (north part of sampling area)
16	19	X	X	In critical habitat just south of former vehicle corridor to Patton Valley (north part of sampling area)
17	19		X	In critical habitat in middle part of sampling area
18	19		X	In critical habitat in southern part of sampling area
19	11		X	In critical habitat in southern part of sampling area

Peirson's milk-vetch was completely censused in each macroplot for the following variables: (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. In addition to these six PMV variables, the number of OHV tracks was also recorded. These seven variables were recorded separately for each 25m x 25m cell. Macroplots are located using a global positioning system (GPS) with waypoints entered into each GPS unit corresponding to the beginning and end of each 25m x 25m cell. Figure 3 shows the numbering system used in 2017.

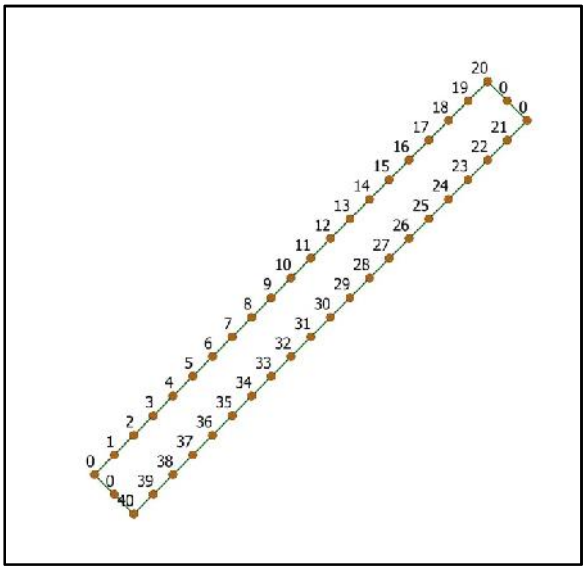

Figure 3. Waypoint numbering system used in 2017 for monitoring each macroplot.

System used to collect data in 2014-2016. The following describes the system used to collect monitoring data in 2014, 2015, and 2016. The waypoints numbered 0 are for navigation purposes only and have no data recorded for them. The observers begin the monitoring at the 0 point at the southwest point along the upper edge of the macroplot. They then set the GPS unit to navigate toward waypoint 1. Observer 1 (with the GPS) stays on the top (left edge) of the belt transect, while the second observer stays 25m away from Observer 1 on the right edge of the transect (if there is a third observer, that observer traverses the center of the belt). These observers then count and record the number of plants/tracks in each of the seven categories for the cell ending at waypoint 1 (this is Cell 1; see Figure 2). Those values are recorded in the GPS unit under waypoint 1. The observers then continue recording data for cells 2-20 (the top row of cells) and navigate down to the waypoint 0 at the southeast corner of the lower edge of the macroplot. Observer 1 continues down the lower (left) edge of the macroplot while Observer 2 stays 25m away on the right edge of the transect (which is the middle of the macroplot). This continues until the data for the last cell is recorded under waypoint 40 (this is Cell 40; see Figure 2).

Modified system used to collect data in 2017. The system described above for years 2014, 2015, and 2016 was modified in 2017 as follows. Before 2017, Trimble GeoExplorer 7 GPS devices were used to both navigate and enter data. The Trimble devices were not particularly user friendly in terms of data entry. An example of this is that the device was not able to record a zero in a data field for a given cell, and there were numerous such zeroes to enter. These fields had to be left blank, leading to some confusion in understanding the downloaded data. In addition, the Trimble operating platform is complex, which led to the complete loss of data for three macroplots in 2016.

To overcome these problems, a new data recording technique was employed in 2017. An Apple iPad was used in the field to record data and navigate. The iPad was connected via Bluetooth to a Dual Universal GPS Receiver to amplify the GPS signal, making its accuracy comparable to that of a Trimble GeoExplorer 7. The Collector for ArcGIS application for iPad (ESRI 2016) was used to directly enter data from each cell into a custom-built ArcGIS Online database. Paper data forms were also used during the 2017 surveys to ensure a backup of all data collected and to compare data on the paper forms with the electronic data collected using the Collector for ArcGIS application as a quality control measure.

Also new to the 2017 surveys was a new, more precise method of circumscribing cell boundaries. Instead of simply using the GPS units to approximate the boundaries, measuring tapes were used to measure the four 25m sides of each cell. Pin flags were then used to mark the four corners of the cells to help guide surveyors in counting plants. Because locating the corners of each cell is still dependent on the accuracy of the GPS units, the actual cell boundaries can still vary by a meter or so between years, but an important source of variability (inconsistent cell boundaries) is removed through this effort.

After counting the numbers of plants in the various categories and the OHV tracks within each of the 40 cells of the macroplot, total macroplot values are then computed for each macroplot by summing the cell values for each of these attributes.

Weather. Precipitation data were obtained from two remote area weather stations (RAWS) in the Imperial Sand Dunes, 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. The locations of these stations are shown in Willoughby (2004a, Map 6). The monthly precipitation shown in the results section is the average of the two RAWS stations for a particular month.

Results

The October-December precipitation in 2017, like that of 2014, 2015, and 2016, was below the threshold of 1.82 inches. Therefore, monitoring consisted of monitoring only the six macroplots as shown in Table 3, except that an additional macroplot, Macroplot 19, was surveyed as a practice plot to test the new data recording system. Because it was surveyed according to protocol the results from that macroplot are included in this report.

The seven macroplots were monitored between April 4 and 7, 2017, as shown in Table 4.

Table 4. Monitoring dates and observers in 2017.

Macroplot	Date Monitored	Observers
19	4/4/2017	Camden Bruner, Jeff Sahagun, Margaret Margosian, and Asdrubal Estrada
15, 16	4/5/2017	Camden Bruner, Connie Fortheringham, Bradd Bridges, and Asdrubal Estrada
13, 1st half of 10	4/6/2017	Camden Bruner, Tony McKinney, Vincent James, and Asdrubal Estrada
6, 8, 2nd half of 10	4/7/2017	Camden Bruner, Connie Fortheringham, Nancy Ferguson, and Asdrubal Estrada

Monitoring results. Table 5 shows the number of plants observed in each of the six categories for each of the macroplots in 2014, 2015, 2016, and 2017. It also shows the number of vehicle tracks observed, the number of cells in which PMV plants were found, and the number of cells in which OHV tracks were observed (there are 40 cells in each macroplot and a total of 280 cells for all seven macroplots).

Table 5. Number of PMV plants counted in six categories, the number of OHV tracks, the number of cells occupied by PMV, and the number of cells with OHV tracks for macroplots in 2014, 2015, and 2016. Macroplot 8 was not monitored in 2014. Macroplots 10, 15, and 16 were monitored in 2016 but the monitoring data was lost due to an error with the GPS unit used to record the data.

Macro plot	Year	Num Seed-lings	Num Flower-ing	Total	Num > 1 yr	Num w OHV Damage	Num w Other Damage	Num OHV Tracks	Num Cells Occupied by PMV	Num Cells w OHV Tracks
6	2014	0	0	0	0	0	0	12	0	8
	2015	0	0	0	0	0	0	0	0	0
	2016	55	0	55	0	0	0	186	3	30
	2017	619	5	624	0	0	1	3	11	3
8	2014	NA	NA	NA	NA	NA	NA	NA	NA	NA
	2015	554	0	554	0	1	0	43	16	20
	2016	402	54	456	7	2	0	155	13	31
	2017	257	0	257	0	0	0	21	23	8
10	2014	268	10	278	4	0	0	0	7	0
	2015	770	0	770	0	0	0	6	11	2
	2016	NA	NA	NA	NA	NA	NA	NA	NA	NA
	2017	1,538	5	1,543	4	0	0	3	22	2
13	2014	1,133	65	1,198	19	0	0	0	17	0
	2015	1,374	11	1,385	3	0	0	6	15	6
	2016	5,519	17	5,536	25	0	0	4	21	2
	2017	13,434	82	13,516	8	0	183	0	38	0
15	2014	683	3	686	2	0	0	11	20	9
	2015	10	0	10	0	0	0	12	3	5
	2016	NA	NA	NA	NA	NA	NA	NA	NA	NA
	2017	1,171	2	1,173	0	0	1	0	32	0
16	2014	144	1	145	1	0	0	3	12	1
	2015	0	0	0	0	0	0	18	0	11
	2016	NA	NA	NA	NA	NA	NA	NA	NA	NA
	2017	367	0	367	0	0	1	0	19	0
19	2014	NA	NA	NA	NA	NA	NA	NA	NA	NA
	2015	NA	NA	NA	NA	NA	NA	NA	NA	NA
	2016	NA	NA	NA	NA	NA	NA	NA	NA	NA
	2017	1,329	15	1,346	0	3	4	48	25	6
Total	2014	2,238	81	2,319	26	0	0	142	64	83
	2015	2,708	11	2,719	3	1	0	85	45	44
	2016	5,976	71	6,047	32	2	0	345	37	63
	2017	18,715	109	18,826	12	3	194	75	170	19

The macroplots used for the 2014-2017 monitoring were chosen based on the fact that they encompassed rather high numbers of plants during the 2005 surveys. The total number of plants that would have been observed in the macroplots had they existed in 2005 has been estimated. Table 6 shows the total number of PMV individuals observed by macroplot in 2014, 2015, 2016, and 2017 compared to the estimated total number of individuals per macroplot based on the data from the 2005 sampling. The 2005 estimated number is based on the numbers of plants in the 2005 sampled cells that overlapped the macroplot. Because not all of the macroplots' cells were sampled in 2005, the actual number of plants in each macroplot in 2005 was likely higher (perhaps considerably higher) than the number shown in Table 6.

Table 6. Total number of PMV plants observed by macroplot in 2014, 2015, 2016, and 2017 compared to the estimated number of plants per macroplot based on 2005 sampling. Macroplot 19, which was sampled for training purposes in 2017, is not included here.

Macroplot	Total 2014 Plants	Total 2015 Plants	Total 2016 Plants	Total 2017 Plants	Estimated Total 2005 Plants
6	0	0	55	624	387
8	NA	554	456	257	473
10	278	770	NA	1,543	673
13	1,198	1,385	5,536	13,516	3,159
15	686	10	NA	1,173	8,732
16	145	0	NA	367	4,646
Total	**2,307**	**2,719**	**6,047**	**17,480**	**18,070**

Figure 4 shows the total number PMV plants counted in the collection of 6 macroplots in 2014, 2015, 2016, and 2016, compared to the estimated number that would have been counted in 2005. Seedlings and nonflowering plants are shown in the lower, blue parts of each bar, while flowering plants are shown in the upper, pink part of each bar. The numbers of flowering plants were so low in 2014-2017, the top bars are barely discernible for those years (the top bar is not discernible at all for 2015). Macroplot 19 numbers are not included in the totals for 2017 because that is not one of the six macroplots that are monitored in years with October-December rainfall of less than 1.82 inches. Data for macroplots 10, 15, and 16 were lost for the year 2016 and are similarly missing for Macroplot 8 in 2014; thus, these data are not included in the totals. As discussed above, the values for 2005 are underestimates because not all the cells in the macroplots were sampled in 2005.

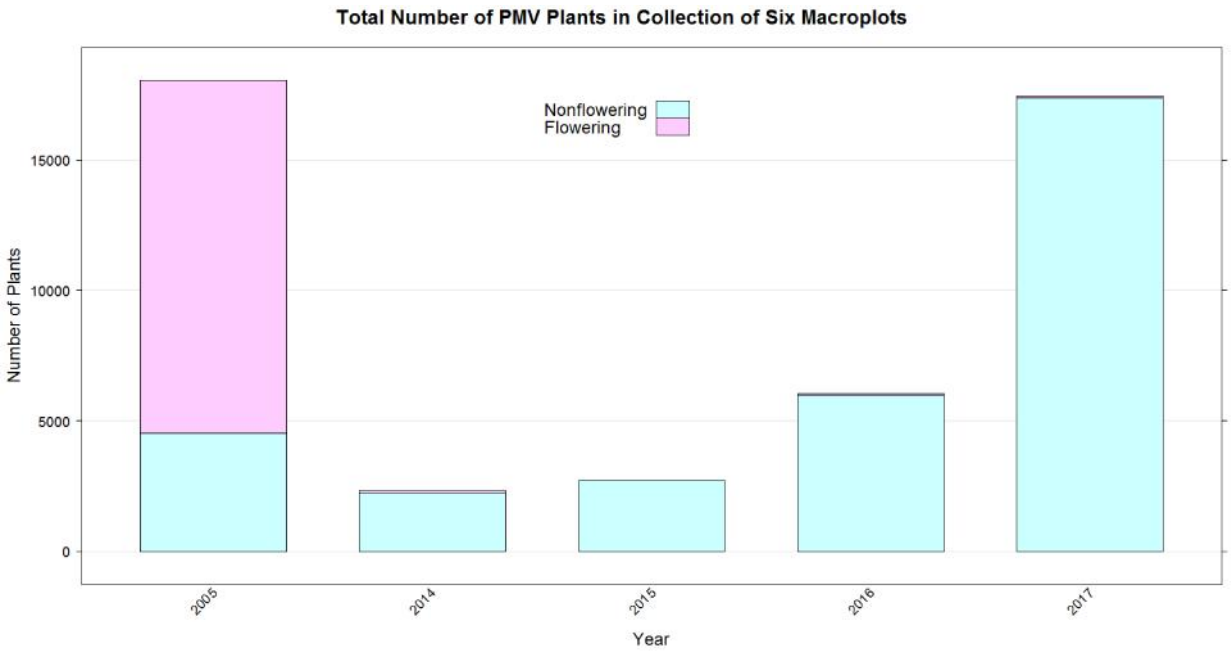

Figure 4. Total number of Peirson's milk-vetch plants counted in the collection of 6 macroplots in 2014, 2015, 2016, and 2016, compared to the estimated number that would have been counted in 2005. Seedlings and nonflowering plants are shown in the lower, blue parts of each bar, while flowering plants are shown in the upper, pink part of each bar. The numbers of flowering plants were so low in 2014-2017, the top bars are barely discernable for those years (the top bar is not discernable at all for 2015). Macroplot 19 numbers are not included in the totals for 2017 because that is not one of the six macroplots that are monitored in years with October-December rainfall of less than 1.82 inches. Data for macroplots 10, 15, and 16 were lost for the year 2016 and are similarly missing for Macroplot 8 in 2014; thus, these data are not included in the totals. The values for 2005 are underestimates because not all the cells in the macroplots were sampled in 2005.

Weather data. Table 7 shows the weather data collected at the two RAWS for growing seasons 2013-2014, 2014-2015, 2015-2016, and 2016-2017. The 50-year growing season average of seven WRCC stations in the vicinity of the dunes (Willoughby 2004a) and the RAWS is given for comparison (the average of the WRCC weather stations are used for averages between growing seasons 1967-1968 to 1999-2000; the RAWS data are used after that).

Table 7. Growing season precipitation at the Imperial Sand Dunes for growing seasons 2013-2014, 2014-2015, 2015-2016, and 2016-2017. The 50-year growing season average of the WRCC stations in the vicinity of the dunes and the RAWS is given for comparison. All units are in inches.

Growing Season	Oct-Dec ppt.	Jan-Mar ppt.	Total Growing Season ppt.	Long-term Growing Season Average ppt. of all WRCC Stations
2013-2014	0.43	0.06	0.49	2.00
2014-2015	0.33	1.01	1.34	2.00
2015-2016	0.22	0.50	0.72	2.00
2016-2017	1.11	1.46	2.57	2.00

Growing season 2016-2017 was substantially wetter than the three previous growing seasons. Although the October-December precipitation did not meet or exceed the 1.82 inch threshold that would have triggered more intensive monitoring, it was more than twice that of the next highest of the four seasons (2013-2014). Except for 0.22 inches in very early October, almost all of the October-December 2016 precipitation came in late December, from December 21 onward. This had implications for the phenology of the 2016-2017 cohort of plants, which will be discussed below.

The total 2016-2017 growing season precipitation, 2.57 inches, was well above the long-term average, with most of the precipitation coming between January-March 2017, mostly in February.

Figure 5 graphs Algodones Dunes growing season precipitation between 1967 and 2017. The top panel of the graph shows the precipitation in the first half of each growing season, October through December. The middle panel graphs the precipitation in the second half of each growing season, January through March. The bottom panel shows the precipitation for each complete growing season. Until 1999 the data are the average of several weather stations to the east and west of the Dunes, as discussed above. From 1999 onward the data are the average of the two RAWS stations established in the Dunes (at Cahuilla and Buttercup). Dotted lines in each panel show the 1967-2017 average for each period and allow comparison of a particular growing season's precipitation to the long-term average precipitation for that growing season (or half growing season). The 2016-2017 growing season exceeded the long-term average precipitation for the entire period as well as for both halves of the growing season. Prior to 2016-2017, the last growing season that exceeded (barely) the long-term average was 2010-2011, but the rainfall was unequally distributed between the two halves, with more of it coming during the October-December period. The last growing season in which rainfall was well above average in both the October-December and January-March periods was 2004-2005, a banner year for PMV.

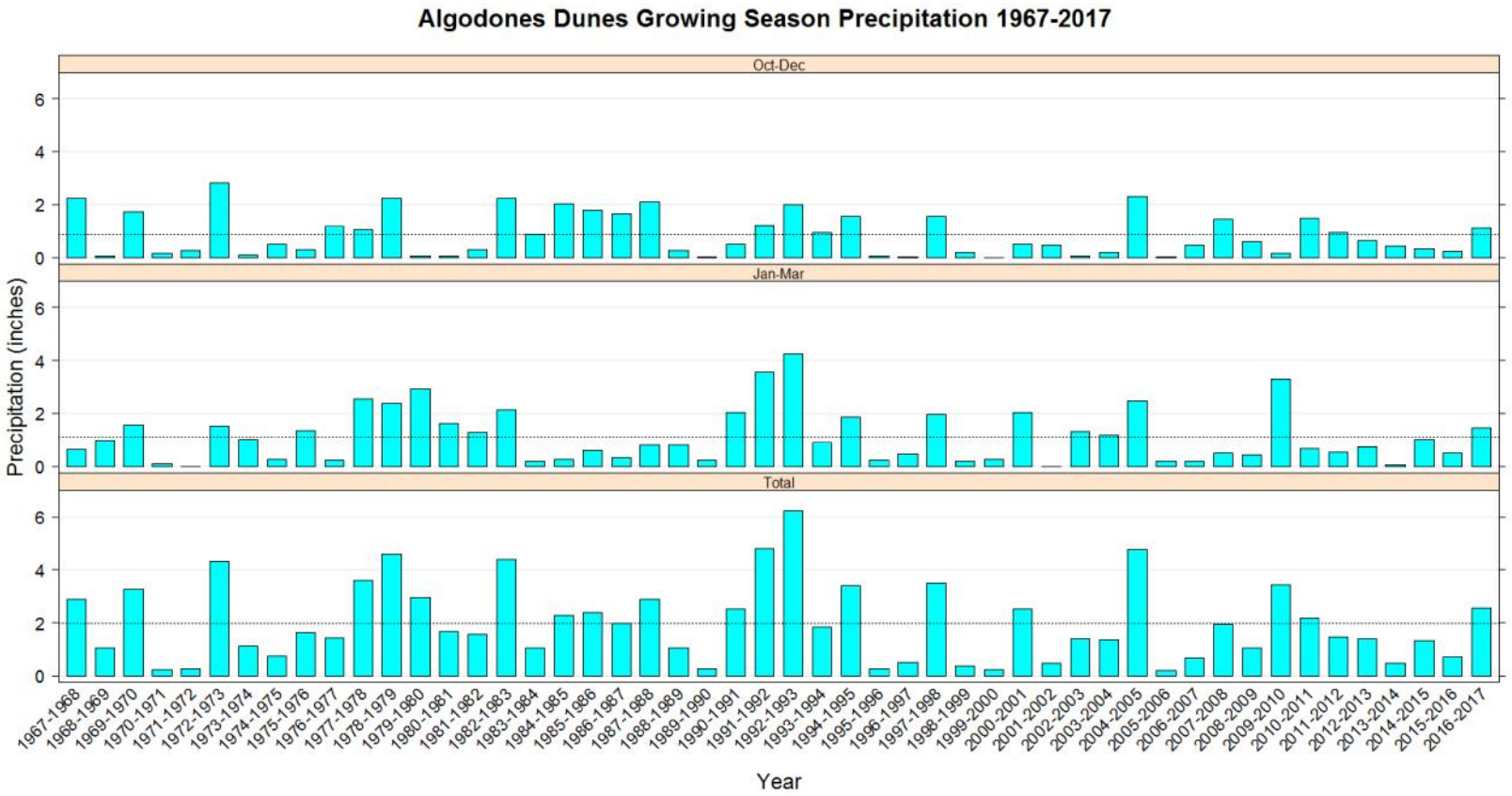

Figure 5. Growing season precipitation at the Imperial Sand Dunes between 1964 and 2016. The growing season is defined as the period October through March. The top panel shows the precipitation in the first half of each growing season, October through December. The middle panel graphs the precipitation in the second half of each growing season, January through March. The bottom panel shows the precipitation for each entire growing season. Until 1999 the data are the average of several weather stations to the east and west of the Dunes. From 1999 onward the data are the average of the two RAWS stations established in the Dunes (at Cahuilla and Buttercup). Dotted lines in each panel show the 1964-2016 average for each period.

Figure 6 shows the monthly distribution of rainfall for growing seasons 2013-2014, 2014-2015, 2015-2016, and 2016-2017. Note that precipitation in December and February 2017 was higher than that of any other of the months in the entire four-year period. Note, too, that some months experienced no precipitation at all, including March 2017.

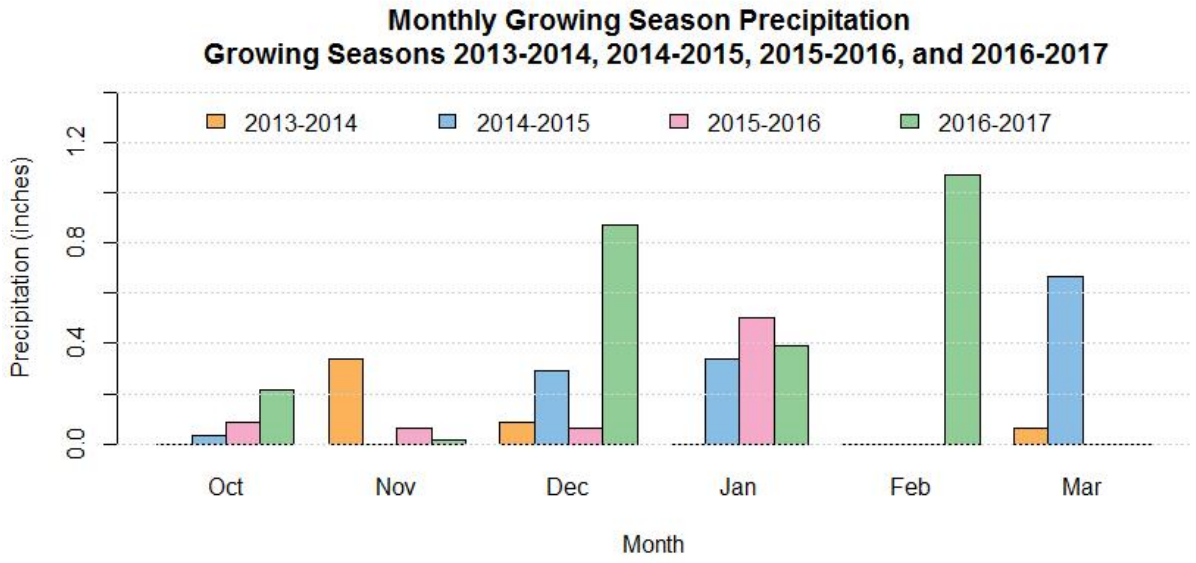

Figure 6. Monthly growing season precipitation for the 2013-2014, 2014-2015, and 2015-2016 growing seasons. Monthly values are the average of the two RAWS for months in which both RAWS were operable, or the precipitation recorded at the single operable RAWS for months in which one of the RAWS was offline (this applies to the 2013-2014 and 2014-2015 growing seasons; no RAWS were offline in 2015-2016).

OHV impacts and tracks. As Table 5 shows, three of the PMV plants counted in the 2016 survey showed evidence of OHV damage.[2] All three of these plants were found in Macroplot 19, an area that is closed to OHV because it is part of the area designated as PMV critical habitat. This compares to two plants with OHV damage in 2016, one plant in 2015, and 0 plants in 2014.

OHV tracks totaled 75 in 2017. Twenty four of these tracks were found in macroplots 6 and 8, both of which are in areas open to OHV use. Three tracks were observed in Macroplot 10, an area closed to OHV use, and 48 tracks were found in Macroplot 19, which as noted above is

[2] A determination of OHV damage is made when a plant shows damage (e.g., a broken stem) and a vehicle track crosses the area where the plant occurs.

closed to OHV use. The 75 OHV tracks observed in 2017 compares to 325 tracks in 2016, 85 tracks in 2015, and 142 tracks in 2014.

Impacts from sources other than OHV use. A total of 194 plants were observed with non-OHV damage in 2017. Of this total, 191 plants were found to be wilted or broken from unknown causes and 3 were accidentally damaged by surveyors during counting, owing to the difficulty of counting in areas with high densities of plants.

Discussion

Distribution and abundance. For the first time in the four years of the current PMV monitoring program growing season rainfall was above average, both for the growing season as a whole and for both halves (Figure 5). PMV plants responded positively to this increased rainfall: a total of 18,826 plants were counted in 2017 across the seven macroplots monitored (including Macroplot 19 which was monitored as a training exercise). Not counting Macroplot 19, there were 17,480 total plants in 2017 (Table 6), compared to 6,047 in 2016, 2,719 in 2015, and 2,307 in 2014. The 2017 total of 17,480 plants is almost as high as the estimated number of plants that were counted in these macroplots in 2005, though as discussed earlier, the 2005 number underestimates the true number of plants that would have been found in 2005 because no all of the cells in each of the macroplots were counted in 2005.

As in previous years, Macroplot 13 supported the largest number of plants with 77% of the plants observed. Macroplot 10 was the next most populated macroplot, accounting for almost 9% of the total. Macroplot 15 (7%), Macroplot 6 (4%), Macroplot 16 (2%), and Macroplot 8 (1%) account for the rest of the plants. Based on the 2005 sampling (Willoughby 2005), there is a north-south gradient in terms of number of plants, with the southern part of the Dunes supporting more plants than the northern part. Thus, the larger number of plants observed in macroplots 13 compared to the number observed in macroplots 6 and 8 would be as expected given that the former macroplot is in the southern part of the Dunes and the latter macroplots are in the northern part. Macroplot 10 is closer to Macroplot 13, so the fact that its numbers are higher than macroplots 6 and 8 is also to be expected. Perhaps most surprising is that Macroplot 16, also in the southern dunes, supported only 2% of the plants observed in 2017. This apparently is not related to a north-south rainfall gradient because Macroplot 19, in the extreme southern part of the dunes, contributes 7% of the total number of plants when all seven macroplots are considered.

Most of the plants observed in 2016 (91.5%) were in Macroplot 13, with 7.5% in Macroplot 8 and 1.0% in Macroplot 6. This is similar to the distribution among these macroplots in 2015 and 2014 (although Macroplot 8 was not monitored in 2014). Based on the 2005 sampling (Willoughby 2005), there is a north-south gradient in terms of number of plants, with the southern part of the Dunes supporting more plants than the northern part. Thus, the larger number of plants observed in Macroplot 13 compared to the number observed in macroplots 6 and 8 would be as expected given that the former macroplot is in the southern part of the Dunes and the latter macroplots are in the northern part. Based on 2005 data, the number of plants in macroplots 15 and 16, both of which are in the southern Dunes, would also be expected to be higher than in macroplots 6 and 8, but the lack of data from those macroplots in 2016 does not allow an evaluation of this.

Stage-class composition. Almost all (99%) of the plants counted in 2017 were seedlings and young, non-flowering plants. The plants observed appeared to represent two or perhaps three cohorts. The first cohort likely germinated in response to late December rains. These plants were the largest observed (between 10 and 15 inches tall) and a few of these were flowering. Another cohort may have germinated in response to rather light rains in January and a third cohort certainly germinated after rather substantial mid-February rains. These plants were still seedlings and small juveniles at the time of the early April monitoring.

Some of the plants from the late December cohort may have persisted to the flowering stage subsequent to monitoring, but it is unlikely that the February cohort flowered in 2017.

The stage-class distribution of plants in 2017 is similar to that observed in the previous three years of monitoring, with almost all of the plants observed being in the seedling and non-flowering category (Figure 4). The disproportionate number of non-flowering plants in 2017 is likely the result of uneven distribution of rainfall through the growing season: despite the fact that the first half (October-December) of the growing season had above average precipitation, most of this rain fell in late December, leaving insufficient time for plants to flower by the time of monitoring. Contrast this to the stage-class distribution in 2005 when 75% of the plants were flowering at the time of monitoring (Figure 4). The 2004-2005 growing season experienced rainfall that was both much higher than average and well distributed throughout both the early and late halves of the growing season (Figure 4).

Only 12 out of 18,226 plants (0.06%) observed in 2017 were greater than one year old. This is likely reflective of the below-average growing season precipitation in the years 2014-2016. Given the fact that there was no precipitation at all in both February and March 2016 (Figure 6), it is quite likely that the seedlings observed in late February and early March 2016 did not survive to flower in 2016, let alone survive summer 2016.

Porter et al. (2005) and Phillips and Kennedy (2005) noted that PMV possesses two different strategies for seed production. Plants that flower early in the growing season have time to flower and set seed during the same season. Porter et al. state there is approximately 90 days between germination and flowering. Plants that germinate later in the growing season do not flower in that growing season. Rather, they depend upon surviving through the summer to flower and produce seeds in the subsequent growing season. The former strategy appears to produce the largest quantity of seed simply because the numbers of same-season flowering plants are much higher (Phillips and Kennedy 2005 and 2006; Willoughby 2005 and 2006), but the latter strategy certainly also works to put seeds into the seed bank. Although 1-year old and older plants are far fewer, they produce much more seed than same-season flowering plants (Porter et al. 2005, Phillips and Kennedy 2005). Although the numbers of plants observed in 2006, following a dismal growing season, were low, Willoughby (2006) concluded that all of the plants must have been one or more years old: there simply was not enough rain to stimulate any germination of PMV in the 2005-2006 growing season.

OHV impacts and tracks. Only three plants showed evidence of damage from OHV use in 2017, all of which were in Macroplot 19, which is closed to OHV use because it is PMV critical habitat. Forty-eight OHV tracks were also observed in Macroplot 19. Macroplot 19 is very close to the Mexican border, so it is possible the tracks and damage originated from U.S. Border Patrol activities rather than or in addition to recreational OHV trespass into the Macroplot. Twenty-four vehicle tracks were counted in macroplots 6 and 8, both of which are open to OHV use. Three tracks were observed in Macroplot 10, which is inside PMV critical habitat and therefore closed to OHV use. The OHV activity inside macroplots 10 and 19 may indicate the need for increased signage and/or increased ranger patrols along the critical habitat borders.

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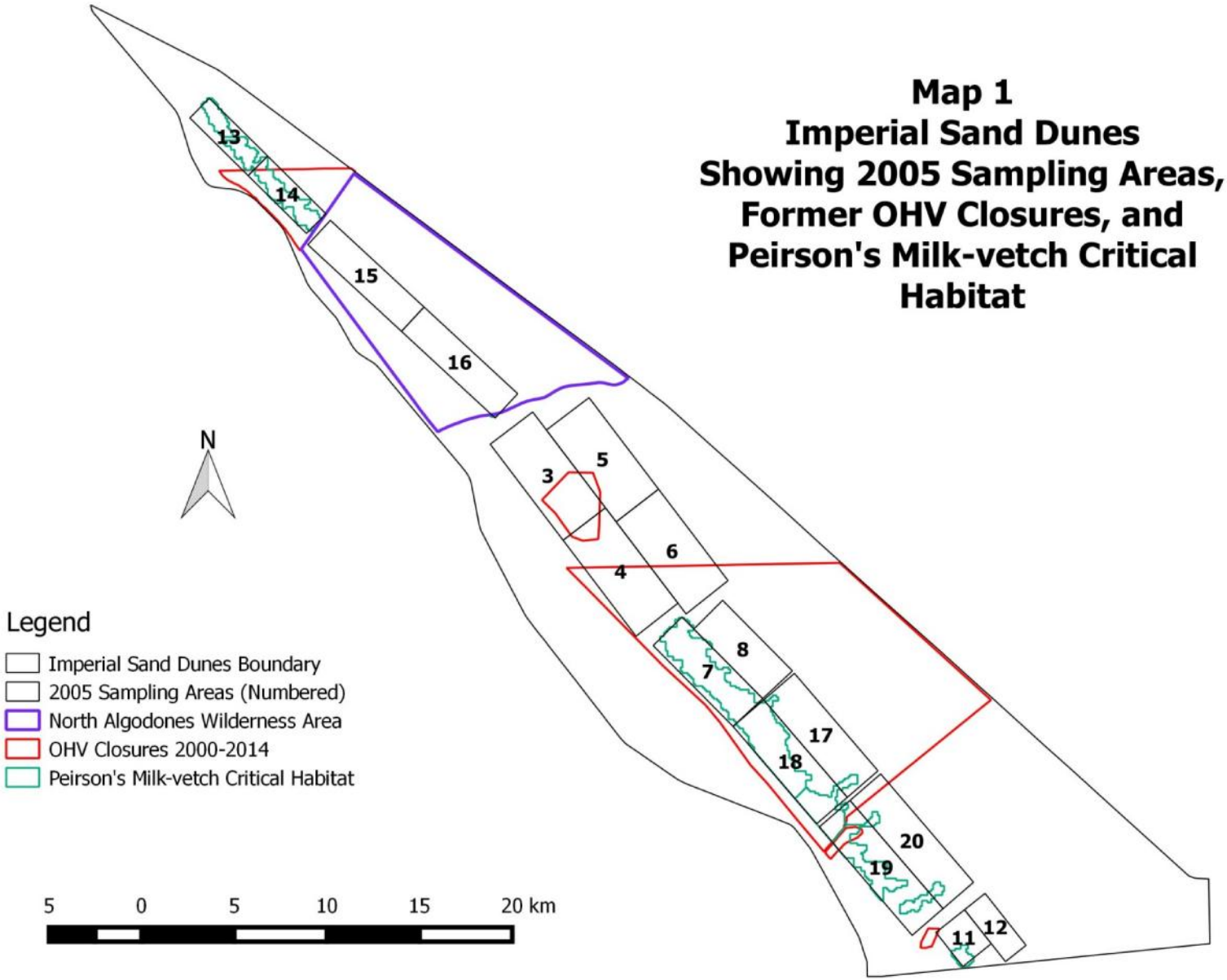
Map 1
Imperial Sand Dunes
Showing 2005 Sampling Areas,
Former OHV Closures, and
Peirson's Milk-vetch Critical
Habitat
N
Legend
Imperial Sand Dunes Boundary
2005 Sampling Areas (Numbered)
North Algodones Wilderness Area
OHV Closures 2000-2014
Peirson's Milk-vetch Critical Habitat
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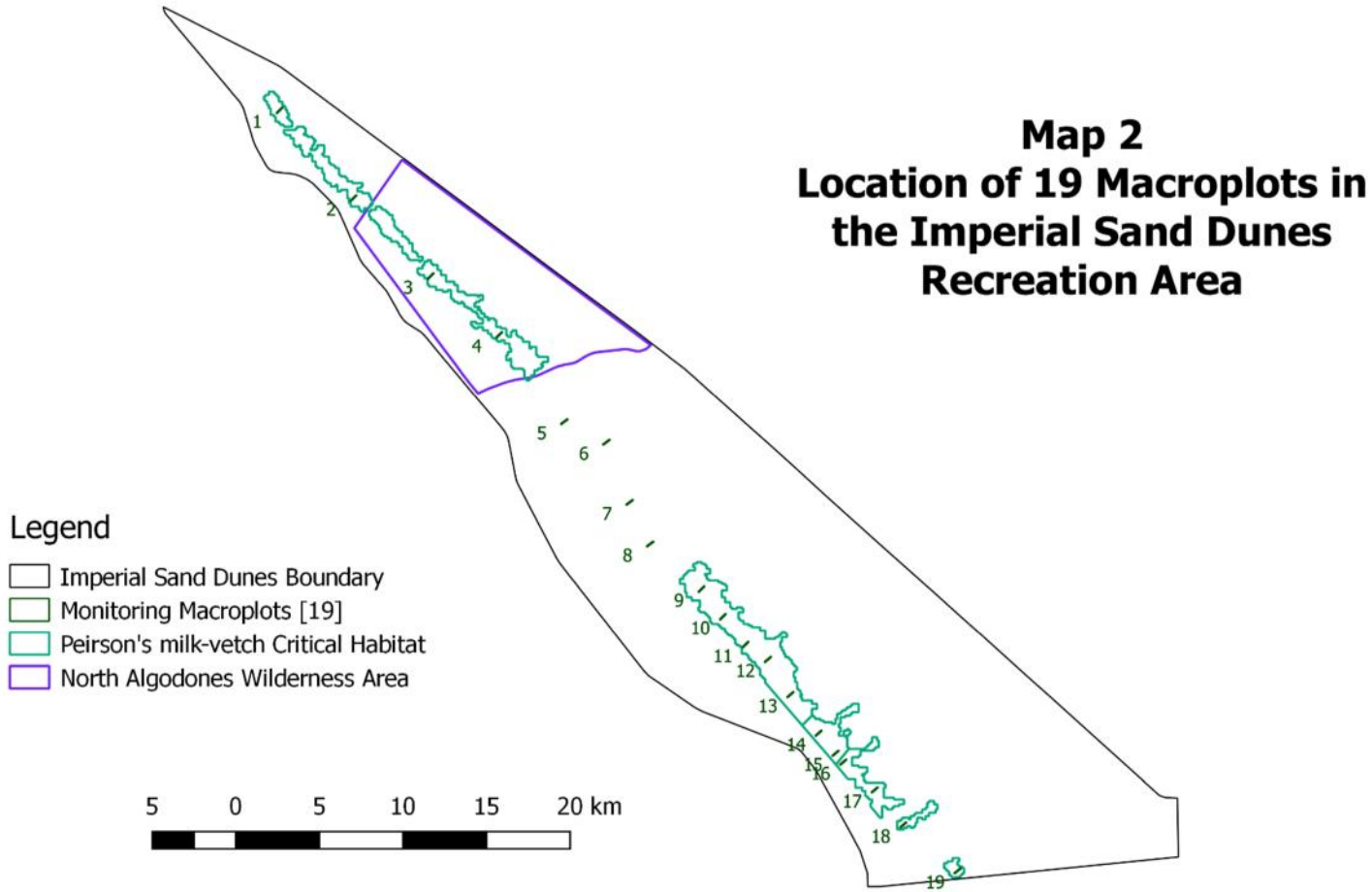
Map 2
Location of 19 Macroplots in the Imperial Sand Dunes Recreation Area
Legend
Imperial Sand Dunes Boundary
Monitoring Macroplots [19]
Peirson's milk-vetch Critical Habitat
North Algodones Wilderness Area
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