2022 Annual Progress Report
Bakersfield Cactus (Opuntia basilaris var. treleasei) Restoration Project on Wind Wolves Preserve

Prepared for the California Department of Fish and Wildlife
California Endangered Species Act - Research and Management Permit No. 2081(a)-12-01-RP

Prepared By:
D. Carrillo, M. Dabulamanzi
Wind Wolves Preserve
16019 Maricopa Hwy
Bakersfield, CA 93311
February 1, 2023
# TABLE OF CONTENTS

**Introduction** .................................................................................................................................................. 3

**Study Area** .................................................................................................................................................. 4
  - Source Population ..................................................................................................................................... 4
  - Introduction Sites .................................................. ..................................................................................... 5

**Methods** .................................................................................................................................................... 8
  - Pad Collection .......................................................................................................................................... 8
  - Planting Technique ................................................................................................................................. 8
  - Planting Dates ........................................................................................................................................ 10
  - 2021-2022 Planting Season ............................................ ........................................................................ 10
  - Data Collection and Monitoring. .............................................................. .................................................. 11

**Results** ..................................................................................................................................................... 12
  - Cluster Health ................................................................................................................................. 12
  - Pad Growth ........................................................................................................................................ 13
  - Mortality ............................................................................................................................................. 15

**Discussion** ............................................................................................................................................. 16
  - Overall Health and Pad Growth ........................................................................................................ 16
  - Management Implications ................................................................................................................. 17
  - Future Monitoring ............................................................................................................................. 17

**Acknowledgments** ................................................................................................................................. 18

**References** ............................................................................................................................................... 19

**Appendix I.** ............................................................................................................................................. 20
  - Bakersfield Cactus Monitoring Protocol .......................................................... ...................................... 20
  - Figure 19 .............................................................................................................................................. 21
  - Figure 20 .............................................................................................................................................. 23
  - Monitoring Protocols 2012-2016 ................................................................................................... 24
INTRODUCTION

Bakersfield cactus (Opuntia basilaris var. treleasii) is endemic to the southeastern corner of the San Joaquin Valley. It was federally and state-listed as endangered in 1990. The species faces multiple threats to survival including ongoing habitat conversion for agricultural and urban uses, off-road vehicle activity, oil and gas development, sand mining, substrate erosion, competition from invasive annual grasses, and wildfire, among others (U.S. Fish and Wildlife Service 2011). Their survival and long term recovery requires innovative and proactive conservation measures.

One of the largest extant populations of Bakersfield cactus, the Pleito Hills population, is found on Wind Wolves Preserve, a 93,000-acre nature preserve owned and managed by The Wildlands Conservancy. The Pleito Hills population is designated “Element Occurrence 44” in other documents on the species (Cypher et al. 2011; U.S. Fish and Wildlife Service 2011). According to the January 12, 2011 status survey, 750-1000 plants were documented in the population. However, on September 10, 2011, a lightning-ignited fire known as the Knob fire swept through the entire population, causing severe damage. The wet winter of 2010-2011 produced a dense growth of annual grasses and forbs creating dry fine flashy fuel, which in turn produced intense heat and direct flame exposure. Figure 1 shows a portion of the population less than an hour after the fire moved through. Through transect sampling, it was estimated that 11% of the cactus clumps in the population were killed by the fire, and 53% were considered severely damaged. Damage from the fire was progressive, with burned pads slowly dying from the initial effects of intense heat.

Figure 1. Pleito Hills population of Bakersfield cactus within an hour after the September 10, 2011 Knob fire.

On October 25, 2011, six weeks after the fire, pad response was documented (Figure 2). Plants with moderate to severe damage grew numerous secondary pads. The majority of damaged pads with new sprouts had turned a light tan color, with minimal or no green color remaining. Many had fallen over, and some completely detached from their basal pads or stems and were lying separated on the ground. Some severely damaged pads were soft and rotting. It appeared that progressive rot could eventually spread and kill the entire plant, including the newly-sprouted secondary pads.
As a result of these concerns, The Wildlands Conservancy obtained a Research and Management Permit under the California Endangered Species Act from the Habitat Conservation Planning Branch of the California Department of Fish and Wildlife on February 13, 2012. The goals of the project were to collect and propagate pads from the Pleito Hills population, and use these new plants to not only increase the Pleito Hills population, but also establish four new populations on Wind Wolves Preserve in the first year. In 2018, The Wildlands Conservancy amended the permit to include collection and planting until 2023, with monitoring and reporting continuing until 2030. The following is a summary of the work done for the 2021-2022 planting season under the amended permit.

STUDY AREA

Source Population

The extant population of Bakersfield cactus on Wind Wolves Preserve is known as the Pleito Hills population. Although it is located on private land devoted to conservation, there is no permanent conservation easement on the 93,000-acre property. The population is situated on a small alluvial fan at the northern foot of the Pleito Hills, east of Pleito Creek, at the southern tip of the San Joaquin Valley. On February 1, 2012, The Wildlands Conservancy established five 100-meter transects in order to assess the damage to the population from the fire, and to attempt to quantify the number of new pads that were present and how many of those were available for collection and propagation.

We sampled 266 plants from the five transects and estimated:

- 9.4% slightly damaged
- 26.3% moderately damaged
- 53.4% severely damaged
- 10.9% killed
Preserve staff counted 8,103 new pads on the 266 sampled plants, yielding a mean of 30.5 new pads on each plant. Taking the 2011 status survey population estimate of 750-1000 plants, and adjusting for our estimated 11% mortality from the fire, we estimated the Pleito Hills population contained 668-890 plants. Given that the remaining plants had a mean of 30.5 new pads per plant, there were approximately 20,374-27,145 new pads in the Pleito Hills population. Therefore, if we were to collect and propagate no more than 5% of the new pads for restoration purposes in 2012, per CDFW guidelines, we could collect 1,019-1,357 pads. The calculations do not include the old pads that survived the fire, so the number of pads that could be collected under the 5% guideline was actually much higher.

Although we were given a 5% CDFW guideline for collection of plant material that would allow us to collect more than 1,019-1,357 pads, we only collected and propagated a total of 800 pads in 2012, ensuring that with some mortality, at least 700 pads would be planted.

**Introduction Sites**

With the help of local experts, four sites were selected for translocating Bakersfield cactus. Monitoring the success of translocated populations will provide insight for future site selection and propagation methods. Although sites are generally chosen for coarse rock and sandy soils, each location differs slightly by soil, slope, grazing regime, and watershed.

Our criteria for site selection, in partnership with Brian and Ellen Cypher, were:

- Soil characteristics
- Elevation
- Topography
- Plant species present

The four sites selected for introduction (Figure 3) were:

- San Emigdio Creek
- Los Lobos Creek
- Muddy Creek
- Salt Creek
Figure 3. Five Bakersfield cactus site locations including the Pleito Hills population and four introduction sites.

All four introduction sites are situated on the valley floor on the alluvial fans of the San Emigdio, Los Lobos, Muddy, and Salt Creek drainages. The soil types are variable, however sites are on well-drained soils with sand, rock, and gravel present. The Natural Resources Conservation Service custom soil reports verified that soils are generally appropriate for each site. These well-drained soils are not only conducive to the growth and survival of cactus, but they also produce less dense invasive annual grasses, thereby reducing the threat of wildfire (Figure 4).
Figure 4. Muddy Creek introduction site, featuring gravel-sand soils, low grass level, and associated plants of cheesebush and allscale saltbush.

All pads planted within a population are located near each other with the exception of the San Emigdio Creek population, which has three planting areas: Spring Wildflower Trail, T-intersection, and San Emigdio Canyon Trail (Figure 5). These areas not only meet criteria for soil and topography, but provide opportunities for educating the public about Bakersfield cactus and current restoration efforts. Each year, Wind Wolves Preserve hosts over 60,000 visitors, and up to 7,000 school children participate in free outdoor education programs. Outdoor education staff are able to show students blooming Bakersfield cactus along the San Emigdio Canyon Trail and educate them about the recovery efforts being taken to save the species from extinction.
METHODS

Pad Collection
Bakersfield cactus pads are collected from the Pleito Hills population between November and February. We select newly-sprouted secondary pads because secondary cactus pads naturally propagate by producing new roots where they lay after falling off of the primary pads.

Pad size is variable. In 2012, we collected smaller pads 5-7 centimeters (cm) high and 2-3 cm wide and larger pads 10-12 cm high and 7-9 cm wide. In subsequent years, we focused on pads of larger size class. We have also progressively increased the number of pads collected, while staying within the guidelines of the permit.

Planting Technique
The 2012-2013 planting season consisted of planting singular pads in planting locations with rebar protection (Figure 6). While monitoring these pads the following summer, Wind Wolves Preserve staff observed some mortality as well as stressed pads. In subsequent years, pads were planted in clusters of seven with variable protection methods (Figures 6-11) to mimic the natural clumps that this species grows in, with the theory that numerous pads planted together will increase the overall success of the pads establishing and exponentially
expanding in foliar cover with secondary, tertiary, and quaternary pads (Figures 7-11). Starting in the 2016-2017 planting season and in all succeeding years, the cacti have been planted in clusters of seven pads with rock protection. Table 1 outlines the number of pads planted in each population during each planting season.

Table 1. Number of pads planted per population for each season (number of clusters shown in parentheses).

<table>
<thead>
<tr>
<th>Planting Season</th>
<th>Pleito Hills</th>
<th>San Emigdio Canyon</th>
<th>Los Lobos Creek</th>
<th>Muddy Creek</th>
<th>Salt Creek</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012-2013</td>
<td>334</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>734</td>
</tr>
<tr>
<td>2013-2014</td>
<td>146 (21)</td>
<td>161 (23)</td>
<td>161 (23)</td>
<td>161 (23)</td>
<td>161 (23)</td>
<td>790 (113)</td>
</tr>
<tr>
<td>2014-2015</td>
<td>161 (23)</td>
<td>161 (23)</td>
<td>161 (23)</td>
<td>161 (23)</td>
<td>161 (23)</td>
<td>805 (115)</td>
</tr>
<tr>
<td>2015-2016</td>
<td>203 (29)</td>
<td>196 (28)</td>
<td>196 (28)</td>
<td>195 (28)</td>
<td>203 (29)</td>
<td>993 (142)</td>
</tr>
<tr>
<td>2016-2017</td>
<td>238 (34)</td>
<td>357 (51)</td>
<td>259 (37)</td>
<td>266 (38)</td>
<td>259 (37)</td>
<td>1379 (197)</td>
</tr>
<tr>
<td>2017-2018</td>
<td>154 (22)</td>
<td>168 (24)</td>
<td>203 (29)</td>
<td>161 (23)</td>
<td>161 (23)</td>
<td>847 (121)</td>
</tr>
<tr>
<td>2018-2019</td>
<td>504 (72)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>497 (71)</td>
<td>1001 (143)</td>
</tr>
<tr>
<td>2019-2020</td>
<td>518 (74)</td>
<td>210 (30)</td>
<td>385 (55)</td>
<td>385 (55)</td>
<td>0</td>
<td>1498 (214)</td>
</tr>
<tr>
<td>2020-2021</td>
<td>252 (36)</td>
<td>203 (29)</td>
<td>392 (56)</td>
<td>399 (57)</td>
<td>217 (31)</td>
<td>1463 (207)</td>
</tr>
<tr>
<td>2021-2022</td>
<td>231 (33)</td>
<td>210 (30)</td>
<td>392 (56)</td>
<td>406 (58)</td>
<td>252 (36)</td>
<td>1491 (213)</td>
</tr>
<tr>
<td>Total</td>
<td>2741</td>
<td>1766</td>
<td>2249</td>
<td>2234</td>
<td>2011</td>
<td>11001 (1465)</td>
</tr>
</tbody>
</table>

Figure 6. Original planting technique used in the 2012-2013 planting season with single-pad plantings.

Figure 7. New planting technique used in 2013-2014 and subsequent years, with pads planted in groups of 7.

Figure 8. Chicken wire protection used on some plantings near livestock grazing.
**Figure 9.** Rebar protection used on over half of the 2013-2016 plantings.

**Figure 10.** Rock protection became the standard method starting in the 2016-2017 planting season.

**Figure 11.** Vaca and t-post protection used on some 2013-2014 and 2014-2015 plantings.

**Planting Dates**
Each year, planting took place between December and March (Table 2). Following 2012-2013, most planting seasons took place in December and January, attempting to establish clusters prior to the first significant rain (>0.25 inches). In 2018, The Wildlands Conservancy acquired a grant under the U.S. Fish and Wildlife Service Partners for Fish and Wildlife Program to fund planting activities at the Los Lobos, Muddy Creek, and San Emigdio populations. These planting areas were undergoing CEQA, NEPA, and Section 106 consultation under the National Historic Preservation Act during the 2018-2019 planting season, and as a result no cactus were planted at these locations, but more clusters were planted at Pleito Hills and Salt Creek. In the 2019-2020 planting season, no clusters were unintentionally planted at Salt Creek due to volunteers planting all remaining cactus pads at Pleito Hills. (Table 2).

**Table 2.** Planting dates for each site during the 2013-2022 planting seasons. “NA” (not applicable) indicates no cacti were planted at the given location that year.

<table>
<thead>
<tr>
<th>Season</th>
<th>Pleito Hills</th>
<th>Muddy Creek</th>
<th>Los Lobos Creek</th>
<th>Salt Creek</th>
<th>San Emigdio Creek</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013-2014</td>
<td>1/9/14</td>
<td>12/14/13</td>
<td>12/14/13</td>
<td>1/9/14</td>
<td>12/7/13</td>
</tr>
<tr>
<td>2014-2015</td>
<td>12/17/14</td>
<td>12/6/14</td>
<td>12/6/14</td>
<td>12/17/14</td>
<td>12/7/14</td>
</tr>
<tr>
<td>2015-2016</td>
<td>1/8/16</td>
<td>1/20/16</td>
<td>1/20/16</td>
<td>1/12/16</td>
<td>1/12/16</td>
</tr>
<tr>
<td>2016-2017</td>
<td>12/17/16</td>
<td>1/29/17</td>
<td>1/19/17</td>
<td>1/12/17</td>
<td>1/15/17, 1/31/17</td>
</tr>
<tr>
<td>2018-2019</td>
<td>2/18/19, 3/1/19</td>
<td>NA</td>
<td>NA</td>
<td>3/8/19, 3/18/19</td>
<td>NA</td>
</tr>
<tr>
<td>2019-2020</td>
<td>1/26/20</td>
<td>2/1/20</td>
<td>1/18/20</td>
<td>NA</td>
<td>12/28/19, 1/5/20</td>
</tr>
<tr>
<td>2020-2021</td>
<td>1/26/21</td>
<td>1/21/21</td>
<td>1/27/21</td>
<td>2/7/21</td>
<td>1/13/21</td>
</tr>
<tr>
<td>2021-2022</td>
<td>2/4/22</td>
<td>1/21/22, 1/25/22</td>
<td>1/22/22, 1/27/22</td>
<td>2/6/22</td>
<td>1/30/22</td>
</tr>
</tbody>
</table>
2021-2022 Planting Season

Preserve staff and volunteers collected 1,491 pads from the Pleito Hills population on December 20, 2021. Pads were placed in plastic totes without lids (approximately 100 pads per tote) and allowed to callus before planting in the field. Staff shifted the pads every couple of days to make sure moisture did not collect near the bottom of the totes. Prior to planting, staff and volunteers scraped a two-foot square area at each planting site to remove non-native vegetation to reduce the threat of fire damage and resource competition. A planting area (about 4 inches deep) was dug using McLeods and shovels, and cactus pads were placed inside using tongs. The soil was filled in such that the cacti did not have exposed roots or buried pad tissue. Pads were planted in groups of seven with random orientation and rock protection (Figure 12).

![Figure 12. Wind Wolves Preserve’s land steward intern planting cactus in the Pleito Hills population.](image)

Data Collection and Monitoring

Data collection protocol varied from 2012 to 2016 (Appendix 1, “Monitoring Protocols 2012-2016”). In 2017, The Wildlands Conservancy staff updated the monitoring protocol to include the use of the ArcGIS Collector application (now called Field Maps). The current Bakersfield Cactus Monitoring Protocol and an example data form are attached in Appendix 1 (“Bakersfield Cactus Monitoring Protocol” and Figure 20, respectively).

With ArcGIS Collector, we mapped all traceable living and dead cacti at all five populations. We recorded the date of mapping, planting year, protection method, tag number, and health index. Examples of health indexes can be seen in Appendix 1, Figure 19. From the mapped cacti, we randomly sampled 50-60 plantings from each population, about 10 from each year, to collect additional data. We recorded the number of secondary, tertiary, and quaternary pads; measured length and width of cluster or pad, in centimeters; and attached a photo. We monitor the health for all plantings for the first two summers after planting, and collect additional data (i.e. number of pads, size, photo) for a random sample of clusters for seven years after planting. Monitoring in 2022 took place between September and October. Pads planted in 2012-2013, 2013-2014, and 2014-2015 were not monitored because they fell outside the seven year monitoring period.
Primary pads are considered all pads rooted in the ground. Secondary pads are any above-ground pads growing from the primary pad. Tertiary pads are pads growing from a secondary pad. Quaternary pads are pads growing from a tertiary pad. Cluster length is the greatest diameter of the cluster. Cluster width is the perpendicular measurement to cluster length. Foliar cover is calculated by multiplying the length and width of the cluster.

RESULTS

Cluster Health
In 2022, we monitored the health of all clusters for the two youngest cohorts, planted in 2020-2021 and 2021-2022. The mean health index for the 2020-2021 cohort was 3.0 (n = 209) across five populations: San Emigdio Creek (4.1, n = 29), Muddy Creek (0.5, n = 57), Los Lobos Creek (3.7, n = 56), Pleito Hills (4.3, n = 36), and Salt Creek (4.1, n = 31). The mean health index for the most recent cohort, 2020-2021, was 4.5 (n = 212) across all five populations: Salt Creek (4.9, n = 35), San Emigdio Creek (4.7, n = 30), Muddy Creek (4.6, n = 58), Los Lobos Creek (4.1, n = 55), and Pleito Hills (4.3, n = 34).

We also monitored health for the random sample of clusters representing each cohort planted from 2015 to 2022. Among the random sample, most cohorts were in fair health (indicated by an index of 3.0) with an overall mean health index of 3.0 (n = 327) (Table 3). Only the 2016-2017 and 2019-2020 cohorts averaged poor overall health indexes with means of 2.3 (n = 50) and 1.6 (n = 46), respectively. The 2021-2022 cohort exhibited the highest overall mean health index (4.8, n = 50) among all age classes. The overall healthiest population this year was San Emigdio, with a mean health index of 4.0 across all cohorts (n = 60). Muddy Creek clusters exhibited the lowest health (Figure 13), with a mean health index of 1.7 across all cohorts (n = 60) (Table 3).

Table 3. Mean health indexes for clusters in the random sample by cohort and population. “NA” (not applicable) indicates no cacti were planted at the given location that year. Sample size, n, is shown in parentheses.
Figure 13. Mean health indexes across five populations between 2015 and 2022, with colored bars representing age cohorts.

Pad Growth
Among the random sample, clusters with a health index of 1-5 (omitting dead clusters with a health index of 0) had, on average, 6.8 secondary pads, 3.5 tertiary pads, and 0.5 quaternary pads across all cohorts and populations (n = 279). The cohort with the most pads overall was the oldest monitored group, planted in the 2015-2016 season with, on average, 12.0 secondary pads, 9.9 tertiary pads, and 1.6 quaternary pads (n = 44) (Figure 14). Among the five populations, San Emigdio Creek clusters averaged the most number of pads overall, with, on average, 10.7 secondary pads, 6.3 tertiary pads, and 1.0 quaternary pads (n = 57) (Figure 15). Muddy Creek clusters averaged the lowest number of pads overall.
**Figure 14.** Mean number of additional pads (primaries excluded) for clusters with a health index of 1-5 of the random sample from each cohort across all populations. Secondary pads are denoted in blue, tertiary in red, and quaternary in green.

**Figure 15.** Mean number of additional pads (primaries excluded) for clusters with a health index of 1-5 of the random sample from each population across all cohorts. Secondary pads are denoted in blue, tertiary in red, and quaternary in green.
Foliar coverage for clusters in the random sample with a health index of 1-5 averaged 0.11 square meters (n = 279), ranging from mean covers of .05 square meters for the newest cohort planted in 2021-2022 (n = 50) to .28 square meters for the 2015-2016 cohort (n = 44). San Emigdio Creek clusters exhibited the most cover with a mean foliar cover of .15 square meters (n = 57), while the other four populations’ means ranged from .08 to .12 square meters.

**Mortality**

Each of the five populations have experienced mortality within the random sample. The percentages of clusters recorded as dead (health index of 0) for each cohort within all populations is shown in Table 4. Overall mortality at Pleito Hills, Salt Creek, and San Emigdio Creek was low, with only 6%, 11% and 3%, respectively. However, the mortality of Los Lobos clusters was 22% (n = 59), and Muddy Creek was 32% (n = 59).

In some cases mortality decreased within the same cohort between monitoring years. For example, there were 5 clusters within the random sample at Salt Creek in the 2016-2017 cohort that had a health index of 0 during monitoring in 2021. However, for the same cohort at Salt Creek during monitoring efforts in 2022, only 4 were given a health index of 0. This indicates newly sprouted pads from what appeared to be a dead cluster during the previous year. These newly sprouted pads are rated with a low health index of 1, indicating the recovering yet fragile condition of the pads (Figure 16).

**Table 4.** Percentage of dead clusters within the random sample for each population.

<table>
<thead>
<tr>
<th>Cohort</th>
<th>Pleito Hills</th>
<th>Los Lobos</th>
<th>Salt Creek</th>
<th>San Emigdio</th>
<th>Muddy</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015-2016</td>
<td>9%</td>
<td>20%</td>
<td>10%</td>
<td>0%</td>
<td>10%</td>
</tr>
<tr>
<td>2016-2017</td>
<td>30%</td>
<td>30%</td>
<td>40%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>2017-2018</td>
<td>0%</td>
<td>10%</td>
<td>10%</td>
<td>0%</td>
<td>30%</td>
</tr>
<tr>
<td>2018-2019</td>
<td>0%</td>
<td>N/A</td>
<td>7%</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>2019-2020</td>
<td>6%</td>
<td>70%</td>
<td>N/A</td>
<td>18%</td>
<td>90%</td>
</tr>
<tr>
<td>2020-2021</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>67%</td>
</tr>
<tr>
<td>2021-2022</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td><strong>TOTAL %</strong></td>
<td><strong>6%</strong></td>
<td><strong>22%</strong></td>
<td><strong>11%</strong></td>
<td><strong>3%</strong></td>
<td><strong>32%</strong></td>
</tr>
</tbody>
</table>
Figure 16. The photo on the left shows cluster #612 at Salt Creek, with an observed health index of 0 (dead) during monitoring in 2020. The photo on the right shows the same cluster in 2021 with one small primary pad and two secondary pads.

DISCUSSION

Overall Health and Pad Growth
Besides impacts to the cactus in the last few years, populations are generally stable and healthy overall. The overall mean health index across all cohorts and populations within the random sample was 3.0. Three populations had mean health indexes exceeding 3.0 (San Emigdio Creek, Salt Creek, and Pleito Hills), while only one population, Muddy Creek, had a health score less than 2. Los Lobos Creek and Muddy Creek experienced high mortality, with 22% and 32% of clusters within the random sample recorded as dead, respectively, contributing to their lower overall health indexes. Cactus health at Salt Creek, Pleito Hills, Los Lobos Creek, and Muddy Creek was impacted by an observed increase in insect herbivory.

Beginning in 2020, Wind Wolves Preserve has experienced outbreaks of grasshoppers and katydids each summer. The outbreak was first observed on June 19th, 2020 while monitoring the Los Lobos Creek population. Staff and volunteers noted that some cactus clusters were dead and many were in poor health due to insect herbivory (Figure 17). Preserve management contacted several experts to identify the insects and notified CDFW of the current threat. David C. Lightfoot, Senior Collection Manager at the University of New Mexico, identified the insects as devastating grasshopper (*Melanoplus devastator*), spurcate grasshopper (*Dissosteira spurcata*), and katydid.

In 2021 and 2022, grasshoppers were observed in abundance at four of the five populations (Salt Creek, Pleito Hills, Los Lobos Creek, and Muddy Creek). Cactus clusters with a health score of 2 or under at these populations generally were part of the younger cohorts (2016-2017 through 2020-2021), suggesting that older (and therefore larger) clusters may be better at surviving this intense herbivory.
Management Implications
Staff informally observed that grasshopper invasions were more intense in areas with higher residual dry-matter of annual grasses. In areas where livestock grazing had reduced the grasses, there appeared to be less grasshoppers present and damage noted. Wind Wolves Preserve Staff will continue to work with its grazing partners to focus prescriptive grazing practices on invasive annual grasses that seem to benefit cactus for reducing insect damage, competition from grasses, and catastrophic wildfire potential.

Future Monitoring
Although ArcGIS Collector has streamlined field data collection, more improvements to the monitoring protocol can be made to increase efficiency and accuracy, as well as to document seasonal occurrences. Monitoring is currently labor intensive and time consuming, as each cluster is individually inspected by preserve staff and volunteers. Documenting pad growth by type (secondary, tertiary, quaternary) can be challenging, specifically in older clusters that have an abundance of pads intersecting one another in the cluster (Figure 18). To minimize the potential for human error, we may simplify future collection methods by recording an estimated total number of pads. Additionally, we may include a new coding system in the protocol to collect data on damage type for any clusters with health indexes less than 5. Adding this metric will allow us to better correlate health with environmental factors, such as insect herbivory.

In the future, we would also like to incorporate the use of unmanned aerial vehicles (UAVs) to collect data for health, pad abundance, and foliar cover. Monitoring will be less labor intensive with UAVs, and flights can occur more frequently with less effort than the current protocol. Additionally, seasonal occurrences like flowering can be documented and may serve as an additional indication of cluster health. Examining the health of existing clusters with high-resolution UAV orthomosaic imagery may also be valuable in predicting the best locations for future planting sites on the preserve.
Figure 18. 2013-2014 cactus cluster displaying significant pad growth.

ACKNOWLEDGEMENTS

We would like to thank numerous staff at The Wildlands Conservancy’s Wind Wolves Preserve who have contributed to this restoration project alongside countless volunteers and students, without whom we could not have had such a successful program. Wind Wolves Preserve relies on the input of experts to save species from extinction. Thank you to Brian Cypher and Ellen Cypher for sharing invaluable experience and insights from their previous work with Bakersfield cactus and assistance selecting establishment sites for new populations. We would also like to thank the U.S. Fish and Wildlife Service for providing financial support for our Bakersfield cactus restoration and education efforts through the Partners for Fish and Wildlife Program.
REFERENCES


APPENDIX I

Annual Progress Report
Research and Management Permit No. 2081(a)-12-01-RP
The Wildlands Conservancy
February 1, 2023

Bakersfield Cactus Monitoring Protocol

We will map all clusters (7 pads/cluster) or individual pads, from every year and population, using ArcGIS Collector on Samsung tablets. We have planted over 1,400 cactus clusters between 2012 and 2018 (2012-2013 plantings were all planted as individual pads). We will record planting data (year, location, protection method, tag number) as well as a health index for the cluster or pad (below). We will then randomly sample 10 clusters per treatment group (population x planting year), examining secondary and/or tertiary growth and area. We will monitor health for all clusters for the first two years after planting. Randomly sampled clusters will be monitored for 7 years following planting.

All pads (2012-2013) and clusters (2013-2017):

Monitoring date
Inspector
Year planted
Protection method
Tag number
Health index (0-5)

Randomly sampled pads and clusters:

Date
Inspector
Year planted
Protection method
Tag number
Health index (0-5)
# of secondary pads
# of tertiary pads
# of quaternary pads
Cluster length (cm)
Cluster width (cm)
Notes
Attach photo

Note: Cluster width and height will be collected to calculate foliar cover area.

The overall health of Bakersfield cactus clusters will be rated using the health index described in Figure 18. All pad types (primary, secondary, tertiary, etc.) will be taken into account.
0 - All pads are dead or missing.

1 - Very Poor. Most pads are dead and/or missing (1-20% alive).

2 - Poor. Significant damage on all or most pads, many missing and/or dead (20-40% alive).

3 - Fair. Roughly half of pads are alive and healthy (40-60% alive).
4 - Good. Most pads are alive and in healthy condition (60-80% alive).

5 - Excellent. Most or all pads are alive and healthy (80-100% alive).

Figure 19. Examples of health indexes, from 0 to 5.
Figure 20. Screenshot of ArcGIS Collector form for Bakersfield cactus monitoring.
In the 2012-2013 planting season, the following data was recorded for each plant:
- Transplant planting date
- Date pad was originally planted in the greenhouse
- Plant ID number
- GPS location
- Height and width of pad at time of introduction
- Height and width of any secondary pad(s)
- Orientation (north-south or east-west)
- A photograph with identification tag visible

For the 2013-2014 planting season, the following data was recorded for each cluster:
- Transplant date/date of planting
- Group ID number
- GPS location
- Number of primary pads
- Number of secondary pads
- Planted in soil or no soil

For the 2014-2015 planting season, the following data was recorded for each cluster:
- Transplant date/date of planting
- Group ID number
- Number of primary pads
- Condition of primary pads (Healthy, Fair, or Poor)
- Number of secondary pads

For the 2015-2016 season, the following data was recorded for primary pads at each cluster:
- Number of pads present
- Number of pads replanted
- Number of pads missing
- Number of pads bit
- Number of pads crushed or rotted
- Number of dead pads