California Fish and Game 100(1):48-60; 2014

Translocation as a conservation measure for endangered Bakersfield cactus

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Bakersfield cactus (*Opuntia basilaris* var. *treleasei*) is a succulent perennial in the cactus family (Cactaceae) and is endemic to Kern County, California. Due to habitat conversion and fragmentation, competition from non-native plants, and ongoing habitat degradation, Bakersfield cactus is listed as federally and state endangered. We tested a technique for establishing new populations of this taxon by translocating Bakersfield cactus pads (i.e., stem segments) and clumps (i.e., intact plants) to two sites within the historic range. Translocated clumps were more successful than pads in terms of survival, growth, and flowering. However, removal of clumps may constitute more of an impact to source populations. Cattle guards were effective in preventing damage from cows. Strategies such as supplemental water during dry summer weather and propagation of pads into small plants prior to translocation are recommended to increase the success of pads. Translocation could contribute significantly to conservation and recovery efforts for Bakersfield cactus.

Key words: Bakersfield cactus, *Opuntia*, restoration, San Joaquin Valley, translocation, transplantation

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Bakersfield cactus (*Opuntia basilaris* var. *treleasei*) is unique in that it is the only cactus native to the San Joaquin Valley. An endemic plant restricted to Kern County, California, the taxon still occurs sporadically throughout its historic range from just north of the Kern River near Bakersfield southward to the southern tip of the valley and into the western foothills of the Sierra Nevada. Bakersfield cactus was once common within its range (Twisselmann 1967), but due to habitat loss and other factors it was listed as an endangered species at both the federal and state levels in 1990 (U.S. Fish and Wildlife Service [USFWS] 1990, California Department of Fish and Game 2005). Despite publication of a recovery plan more than 15 years ago (USFWS 1998), Bakersfield cactus continues to decline; habitat loss and degradation are ongoing, and additional threats have been identified recently (Cypher et al. 2011b, 2014; USFWS 2011).

As with other prickly-pear cacti (*Opuntia*), Bakersfield cactus has flattened stem segments (cladodes) commonly known as pads. The tiny leaves of all prickly-pear cacti appear only on young growth and are soon deciduous. Bakersfield cactus differs from other varieties of beavertail cactus (*O. basilaris*) in that it has rigid spines (Baldwin et al. 2012). Some species of prickly-pear cacti have fleshy fruits known as pears or tunas, but the fruits of Bakersfield cactus are dry. Although Bakersfield cactus does produce seeds, the warm, moist conditions necessary for germination are rare within its range (Benson 1982), and predators readily consume the seeds (E. Cypher, unpublished data). Instead, reproduction is mostly vegetative by means of individual pads detaching from the standing plants and taking root (Twisselmann 1967, Benson 1982); the resulting offspring, thus, are clones of the parent plant. As a result, large masses of stems known as clumps often grow proximate to each other, and individual stems within the clumps are difficult to distinguish. Thus the terms "plant" and "clump" are used interchangeably herein, although either may range in size from a single stem to a meter or more in diameter. Longer-distance dispersal of Bakersfield cactus is mainly downhill due to gravitational movement of shed pads, although downstream movement is possible for plants that grow along watercourses (USFWS 1998). Dispersal distances for seeds and pollen are not known; a solitary bee (*Diadasia rinconis*) has been observed visiting the flowers of Bakersfield cactus (Grant and Grant 1979), but otherwise little is known about the pollination biology of the taxon.

New Bakersfield cactus populations potentially could be established in unoccupied habitat via the translocation of pads and small clumps. Using one or both of these means, small Bakersfield cactus populations have been established in several locations within the Bakersfield city limits (Fiedler 1991, Cypher et al. 2014). Thus, translocation of cactus pads and clumps may constitute a viable strategy for restoring Bakersfield cactus. Although creation of new populations was not identified as a recovery action in either the recovery plan (USFWS 1998) or the 5-year review (USFWS 2011) it is, nonetheless, a strategy that can help to ameliorate past habitat loss. Basic principles of conservation biology suggest that the probability of species extinction can be reduced and the likelihood of long-term viability can be improved by increasing the number of individuals and populations of a species (Primack 1996). Thus, successful establishment of additional populations could contribute in meaningful ways to the conservation and ultimate recovery of Bakersfield cactus. Given the highly fragmented state of remaining natural lands and inherent characteristics of the species, natural dispersal of Bakersfield cactus to unoccupied habitat is highly improbable.

We initially translocated Bakersfield cactus pads and clumps with the objectives of (1) establishing a population of Bakersfield cactus in currently unoccupied habitat, and (2) comparing two methods for conducting such population establishment. Using similar techniques, we conducted a second translocation for the primary purpose of salvaging doomed plants; however, the second translocation provided an opportunity to test additional aspects of the technique.

Although various terminology is used to describe anthropologically-assisted movement of animals and plants, we felt that "translocation" best described our effort. This term has become controversial in recent years as species have been moved outside of their natural ranges; proponents tout the benefits for preventing species extinctions and promoting biodiversity (Schlaepfer et al. 2009, Muller and Eriksson 2013), whereas opponents point out the expense and potential risks to the ecosystem (Fazey and Fischer 2009; Ricciardi and Simberloff 2009a, 2009b). We use the term "translocation" simply to mean the transfer of an individual from one location to another within its historic range. The term "transplantation" is more commonly used for plants, but did not seem appropriate for pads that were not yet rooted.

Materials and Methods

Source population.—Bakersfield cactus pads and clumps were collected from Sand Ridge, a natural feature consisting of eolian sand deposits derived from granite (Soil Survey Staff 2013). Sand Ridge is located approximately 15 km east of the city of Bakersfield (Kern County, California), at the base of the Tehachapi Mountains (Figure 1). The Bakersfield cactus population at Sand Ridge (Element Occurrence 3) is estimated to consist of >10,000 clumps, and is the largest remaining population (Cypher et al. 2011b, 2014). Bakersfield cacti are most abundant on top of the ridge and along the eastern slope, but extend down onto the floodplain of Caliente Creek at the southeastern base of the ridge.

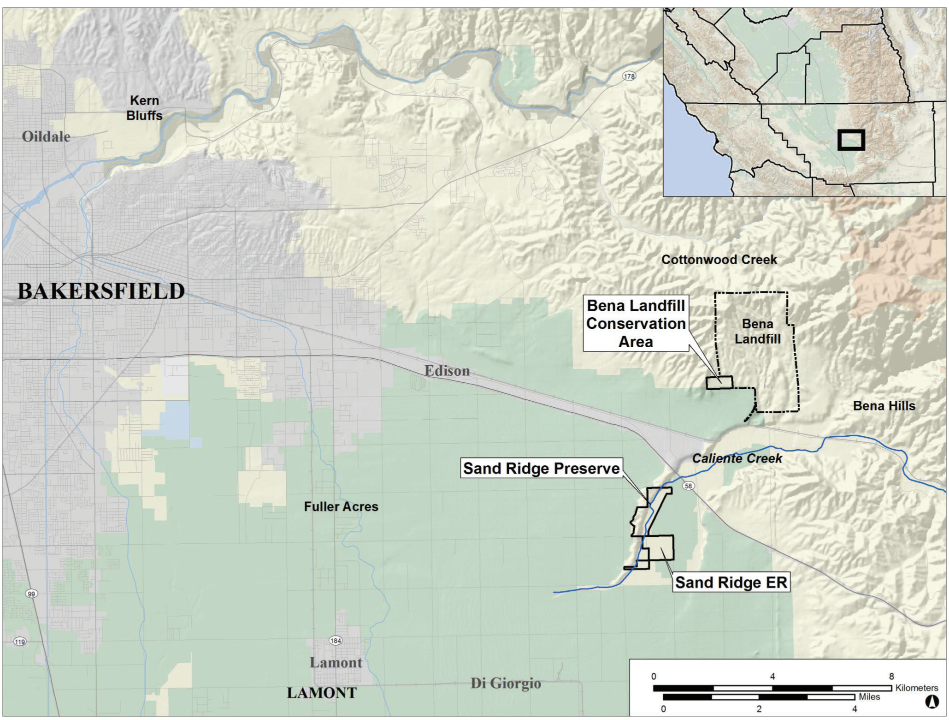

Figure 1.—Locations of two source populations and two recipient sites for translocations of Bakersfield cactus, Kern County, California.

The plant community at Sand Ridge is a relatively unique combination of species from the San Joaquin (Germano et al. 2011) and Mojave deserts. These species are adapted to the arid conditions, hot summers, and the Mediterranean climate, in which rain falls primarily from December through March (Twisselmann 1967, Major 1995). Dominant shrubs and subshrubs on the ridge itself are native and include bladderpod (*Peritoma arborea*), California croton (*Croton californicus*), cheesebush (*Ambrosia salsola*), and desert tea (*Ephedra californica*). Dominant herbaceous species include non-native grasses such as slender wild oats (*Avena barbata*) and ripgut brome (*Bromus diandrus*), and native forbs such as Coulter's jewelflower (*Caulanthus coulteri*), fiddleneck (*Amsinckia* spp.), Kern tarweed (*Deinandra pallida*), and several lupines (*Lupinus* spp.). All plant scientific names cited herein follow Baldwin et al. (2012).

Collection and translocation of Bakersfield cactus were conducted under a recovery permit from the USFWS (TE825573-4) and a research permit (2081(a)-09-15-RP) from the California Department of Fish and Wildlife (CDFW). Permissions were secured from landowners of the source and recipient sites.

First translocation.—Material was collected from the Sand Ridge Preserve (Preserve), a 109-ha conservation area owned by the Center for Natural Lands Management (CNLM; Figure 1). The collection area was on the upper part of the ridge ca. 250 m in elevation. The introduction site was Kern County's 390-ha Bena Landfill Conservation Area (BLCA), which is at the southwestern corner of the Bena landfill property (Figure 1) and will be protected in perpetuity as mitigation. The BLCA is approximately 5 km upstream from the Preserve along Caliente Creek and is centrally located within the historic range of Bakersfield cactus. A number of smaller, extant cactus locations occur just outside the landfill boundaries and were likely contiguous with Sand Ridge historically (Cypher et al. 2011a, 2011b, 2014). In the area of the BLCA where we introduced the cacti, the plant community is primarily annual grassland. Dominant species include non-native annual grasses such as red brome (*Bromus madritensis* ssp. *rubens*) and wild oats (*Avena* spp.), the non-native forb red-stemmed filaree (*Erodium cicutarium*), and the native forbs blue dicks (*Dichelostemma capitatum*) and fiddleneck (*Amsinckia* spp.). Topographically, the area ranges from gently rolling hills to moderately steep slopes with deep ravines. The elevation of the translocation site was ca. 350 m; the soil complex in the BLCA is derived from mixed alluvium and consists of sandy clay loam and gravelly sandy clay loam (Soil Survey Staff 2013).

Ten plants (small clumps) and 25 shed pads were collected on 19 October 2009. This timing was planned to coincide with the onset of winter rains. We followed permit requirements to collect only clumps that had five or fewer pads and that were relatively isolated from other cacti, and to collect pads that had been shed naturally. The east-facing side of each clump was marked so that plants could be planted with the same orientation at the introduction site. We dug at a minimum distance of 15 cm beyond the perimeter of each clump, then transferred it to a bucket that was lined with a large piece of fabric, along with a sufficient amount of soil to cover the roots and stabilize the plant.

By collecting pads that had been shed naturally we avoided damaging living plants. Only one pad was collected per clump to minimize impacts to reproduction at the source site. We collected shed pads that had not yet become rooted to the ground but had already formed a callus at the detachment point. Each collected pad was weighed and the maximum length and width were measured. Pads were transported to the introduction site in individual, labeled paper bags.

On 20 October 2009, we introduced the cactus pads and clumps to the BLCA. Plots were subjectively located throughout the suitable habitat to avoid ground squirrel (*Spermophilus beecheyi*) burrows and other disturbances. Within plots, spacing of cacti roughly emulated the spacing in natural populations. Each of the five plots received five pads and two clumps, which were mapped to facilitate monitoring. Before placing the pads on the ground, we removed thatch from the soil surface and loosened the top few centimeters of soil. Any pad that exhibited root growth was positioned so that the roots were in contact with the soil surface. All other pads were placed in a position that maximized contact between the pad and the soil surface (i.e., flat side down) and were secured with a wooden skewer.

For each clump, we dug a planting hole that was approximately 30 cm in both depth and width. Each clump and its soil were removed from their bucket by grasping and lifting the fabric that was lining the bucket. Clumps were transferred into the planting holes by hand and the holes were filled in with a combination of soil transported from the source population site and soil native to the introduction site. Clumps were transplanted into dry soil and watered after one week (approximately 3.5 liters each). Water was provided again on 25 November 2009. After this date, sufficient precipitation precluded the need for further supplemental watering during that growing season.

To protect the cacti from disturbance associated with cattle ranching on the site we installed 1.5-m metal T-stakes at each of the plot corners to alert ranch hands. In addition, we installed two pieces of crossed, bent rebar over each pad and clump in three of the five plots to discourage cattle from trampling the plants and to test efficacy of this protective mechanism. Thus, a total of 15 pads and 6 clumps were protected by rebar.

We visited the introduction site approximately monthly for the first six months to assess the status of the pads and clumps, then opportunistically thereafter, with the final visit occurring in November 2013. During monitoring visits we evaluated survival of each pad and clump, documented new pad growth and flowering, and removed any vegetation growing immediately next to or overhanging the translocated pads and clumps to reduce competition for light and water. Finally, at the conclusion of the project, we counted the number of live pads present for each plant and assessed damage caused by cattle.

Second translocation.—Bakersfield cactus clumps and pads were collected from an unprotected portion of Sand Ridge immediately north of the Preserve at ca. 280 m elevation that was undergoing active conversion to citrus orchards. The inadequacy of state and federal regulations to protect this species was identified as a threat at the time of federal listing (USFWS 1990) and is one of the ongoing threats to Bakersfield cactus, as summarized in the 5-year review (USFWS 2011). The recipient site for this effort was the Sand Ridge unit of the Bakersfield Cactus Ecological Reserve (Sand Ridge ER; Figure 1), which is owned and managed by CDFW.

The Sand Ridge ER is at the southeastern base of Sand Ridge, on the margin of the Caliente Creek floodplain at an elevation of ca. 195 m. Native Bakersfield cactus occurs in this area but was largely displaced by agricultural conversion prior to state ownership; only the least-disturbed southwestern parcel of the Sand Ridge ER received translocated cactus. CDFW now manages the entire Sand Ridge ER to protect the remaining Bakersfield cactus and as a buffer for the extensive population of cactus on the ridge. The dominant shrub in the Sand Ridge ER is the native scale-broom (*Lepidospartum squamatum*), but a few individuals of native allscale saltbush (*Atriplex polycarpa*) also are present. The herbaceous species composition is similar to that of the BLCA. The topography in the Caliente Creek floodplain is level; soils are derived from alluvium and the soil texture is gravelly loamy coarse sand (Soil Survey Staff 2013).

The second translocation effort took place on 20 January 2011 after the salvaged Bakersfield cactus plants had been buried under a bulldozed mound of sand for approximately one month. The 2 large cactus clumps that we were able to locate under the mound of sand were removed in the most intact units possible, yielding 26 smaller clumps and 28 separate pads, a result of disarticulation that occurred during excavation or transport. Clumps and pads were transported in buckets as in the first effort and planted on the same day. Of the six plots established and mapped, five contained five clumps and four to five pads each; the sixth plot contained the remaining plant material consisting of a single clump and six pads. Planting sites were prepared and clumps planted as in the first effort. In an attempt to improve pad survival and to test the effect of pad orientation on survival success, we partially buried pads in the soil in one of three orientations: horizontal (i.e., flat), vertical (upright), or on edge. All pads and plants were then thoroughly watered; supplemental water was again provided on 25 July 2011. Monitoring took place on 25 July 2011, 27 February 2013, and 1 November 2013. Competing vegetation was sparse and was not removed during this period.

Statistical analyses.—The proportion surviving for each translocation was compared between pads and clumps using contingency table analyses and chi-square tests. For pads in the first translocation we compared the mean weight at initial collection and mean area (length x width) between pads that lived and pads that died using a t-test. T-tests were also used to compare mean number of pads between cacti that flowered and those that did not in both translocations. For the second translocation we used single-factor analysis of variance to compare the number of live pads present per plot in November 2013 among the three orientations of pads that had been planted.

Results

First translocation.—Through May 2011, all 10 translocated cactus clumps were still alive, yielding a 100% survival rate. Among the translocated shed pads, 12 of the 25 were still alive in May 2011 for a 48% survival rate. The proportion surviving was significantly higher for the clumps (χ^2_1=5.33, P=0.021). Although one clump died between May 2011 and November 2013, for an overall clump survival of 90%, mortality among pads was even greater with only 4 of the 25 (16%) alive at the latter time; final clump survival was highly significant when compared to pad survival (χ^2_1=13.73, P<0.001). Among the pads, those surviving to May 2011 were significantly heavier (t_{14}=2.11, P=0.05; $\bar{x}$=34.8 ± 8.2 g [*SE*]) at the time of collection from the source site than those that did not survive ($\bar{x}$=16.2 ± 3.3 g). By November 2013 survival of pads was no longer significantly related to initial pad weights (t_3=1.34, P=0.14), although pads that survived to that point generally were heavier ($\bar{x}$=45.6 ± 17.8 g) than those that died by that time ($\bar{x}$=21.2 ± 4.1 g). Mean initial pad size tended to be larger among pads that survived to May 2011 ($\bar{x}$=42.5 ± 6.9 cm^2) compared to non-surviving pads ($\bar{x}$=29.8 ± 3.6 cm^2), but the difference was not significant (t_{17}=1.64, P=0.12). A similar pattern was observed as of November 2013, when pads that remained alive had an initial mean size of 46.2 ± 10.9 cm^2 compared to non-surviving pads ($\bar{x}$=33.9 ± 4.2 cm^2), but the difference again was not significant (t_4=1.05, P=0.18).

The clumps consisted of one to five pads when translocated in October 2009. Both clumps and pads began producing new pads in spring 2010. By May 2011, 9 of the 10 clumps (90%) and 7 of the 12 (58%) surviving pads exhibited new growth. At that time, clump size ranged from 3 to 11 pads for a mean of 6.4 per plant, which had doubled to a mean of 12.9 (range 3 – 37) by November 2013. By May 2011, the 12 remaining plants that had originated from translocated pads consisted of an average of 2.2 living pads (range 1 – 7), but the original pad was still alive among only 3 of these. For plants originating as pads, the mean number of living pads more than doubled by November 2013 to 6.0 (range 4 – 8). Factoring in both new growth and mortality of individual pads, the net increase in pad number for clumps by May 2011 averaged 2.3 (range 0 – 7), whereas those planted as pads had a mean net increase of 1.2 (range 0 – 4). As of November 2013, the net gain in total number of pads within clumps averaged 8.8 (range -2 – 33), compared to a net gain of 5.0 pads (range 3 – 7) for plants originating as single pads.

Among the 10 translocated clumps, 2 (20%) produced flowers in spring of 2010, 4 (40%) in 2011, 2 (20%) in 2012, and 4 (40%) in 2013. As of November 2013, the 4 clumps that had produced flowers consisted of a mean 19.3 ± 6.2 pads, compared to 7.6 ± 2.2 among the 5 surviving clumps that had not flowered; this difference was significant at α=0.10 (t_4=1.77, P=0.08). Among the 25 translocated pads, only 1 (4%) flowered; it produced a flower in spring of 2010 and again in 2011, then died before spring 2012. Initially, this had been one of the larger pads and weighed 87 g when planted.

As of May 2011, five pads had been shed from the translocated clumps; all were alive and two of the five (40%) had produced new pads. By November 2013, only one of the five (20%) shed pads seemed to be alive and no additional shed pads were observed. The translocated pads did not shed any pads during the course of the study.

In the three plots in which cattle guards were installed, no damage from cattle was observed on any of the six clumps and seven surviving pads as of May 2011. On the two plots where guards were not installed, potential damage from cattle was observed on three of the four clumps (75%) and on one of the five (20%) surviving pads. Thus, 44.4% of unprotected plants sustained possible damage from cattle in the form of broken pads and possibly an eaten flower. As of November 2013, three of the four surviving pads (75%) were protected by cattle guards; the one clump that died did not have a guard. The majority of mortality occurred during the summer months, irrespective of cattle guards (Figure 2).

Second translocation.—As of November 2013, all 26 translocated, salvaged cactus clumps were still alive (100% survival), and more than two-thirds (19/28 = 68%) of translocated pads survived. As in the first effort, the proportion of clumps surviving was significantly higher than the pads (χ^2_1=7.85, P=0.0051). As of November 2013, survival among the pads planted vertically (8/8 = 100%) was significantly higher (χ^2_2=5.31, P=0.071) at α = 0.10 than that of pads planted on edge (6/11 = 55%) or horizontally (5/9 = 56%). The majority of mortality was in the first two years; during the summer of 2013 only one plant originating as a pad died, but two others that appeared dead in February were determined to be alive in November.

New growth was evident among all clumps (26/26; 100%) and many pads (18/28; 64%) by July 2011. Among plants still alive in November 2013, the mean number of pads among translocated clumps was 20.1 (± 2.3) compared with 5.4 ± 0.7 for plants originating as pads. The net gain number in total number of pads per clump cannot be determined because the exact counts were not recorded at the time of translocation; initial clump size

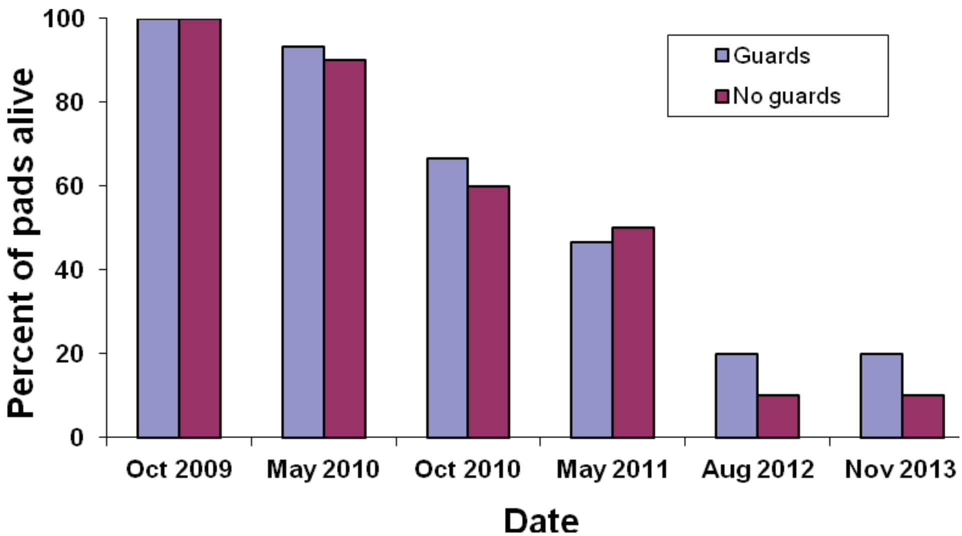

Figure 2.—Percentage of surviving translocated Bakersfield cactus pads by monitoring date at the Bena Landfill Conservation Area, Kern County. In October 2009, 15 pads were planted with cattle guards and 10 pads were planted without cattle guards.

was quite variable and often much larger than in the first translocation. For plants originating as single pads mean net gain in pads by November 2013 was 5.4 ± 0.7 (range 0 – 10). The three pad orientations did not differ in net pad gain ($F_{2,16}$=1.87, P=0.19), although means trended higher for pads planted on edge ($\bar{x}$=5.8 ± 0.53) or vertically ($\bar{x}$=4.4 ± 1.3) than horizontally ($\bar{x}$=2.6 ± 1.0).

By November 2013, the translocated cacti exhibited evidence of both flowering and vegetative reproduction. Eleven of the 26 (42%) translocated clumps produced flowers in 2013 but none of the plants originating as pads flowered. Plants that flowered contained more pads ($\bar{x}$=22.5 ± 4.2) in November 2013 than those that had not flowered ($\bar{x}$=10.7 ± 1.5; t_{14}=2.64, P=0.019). Three shed pads (two from clumps, one from a plant that had originated as a pad) were observed in February 2013 but did not survive the summer. Four recently-shed pads seen in November 2013 (two each from plants originating as clumps and pads) were producing roots.

Discussion

Translocation and reintroduction are strategies that have been employed in conservation efforts for a number of rare plant species (Allen 1994, Given 1994, Falk et al. 1996). These strategies offer immense potential for re-establishing populations on formerly occupied sites or for establishing new populations at suitable sites. However, considerable expense and risk are always involved when moving individuals to new sites; many such efforts have failed and, as a result, all reasonable efforts should be taken to reduce this risk and also to avoid any detrimental effects to source populations. Only through long-term monitoring that documents reproduction in the founders and the presence of new generations can translocations be deemed successful in establishing self-sustaining populations (Fiedler 1991, Godefroid et al. 2011, Drayton and Primack 2012).

Although shed pads that had developed roots were observed in both translocated populations, their long-term survival is uncertain. Seedlings have not yet been observed in either of the present efforts; even if seeds are produced, recruitment for Bakersfield cactus via seedlings may occur only in years of above-average rainfall (Twisselmann 1967, Benson 1982). Ideally, the production of new plants eventually will exceed mortality of existing plants, resulting in expansion of the new populations. Sexual reproduction would expand the genetic diversity of the new populations, helping to increase their long-term viability, but we do not know if any of the flowers produced viable seed. Monitoring of both of the newly-established populations will continue periodically to determine if future generations become established through either sexual or vegetative reproduction.

Survival rates between the two efforts are not directly comparable because our techniques differed somewhat, as did the timing of collection and translocation. The pads in the second effort likely had a higher initial moisture content because they were still attached to clumps until the day of translocation and because substantially more rain had fallen in the preceding month compared to the first effort (California Irrigation Management Information System [CIMIS] 2013). Also, the second translocation effort took place more than a year after the first and, as a result, the data reflect mortality rates over only 34 months, compared to 49 months for the first effort. However, the second translocation effort had undergone two drier-than-normal water years by that time (CIMIS 2013), and the survival rate of comparably-oriented (horizontal) pads remained similar to that observed at 19 months in the first effort, which followed two wetter years.

These efforts were pilot projects, and only the first translocation was designed as a study to test the technique. However, both of these translocations incorporated several of the success factors identified in the literature (Fiedler 1991, Godefroid et al. 2011, Drayton and Primack 2012) including introduction into protected areas of similar habitat, using a stable source population, consideration of species biology, and appropriate management of the recipient site. Additional published success factors should be considered if translocations of Bakersfield cactus are attempted on a broader scale, including the use of larger transplants, outplanting a greater number of individuals, and determining the appropriate source populations based on genetic information.

Clumps exhibited a greater potential for successful translocation than pads, especially in the first effort. Clumps have more resources than pads; an existing root system allows for much faster access to soil moisture, and more stored moisture is available to help survive during dry periods. In contrast, individual pads must expend resources developing a root system, and they are more susceptible to mortality under dry conditions due to a limited reserve of stored moisture. Larger and heavier pads presumably have a greater moisture reserve than smaller pads, as suggested by the observed trends, but the low overall pad survival rates obscured any significant relationship. A similar trend was observed in Bakersfield cactus that was propagated for a restoration project, however, where 100% of large pads survived and only small pads died during the first year (Clendenen and Erickson 2013). The skewers also may have contributed to moisture loss among pads in the first translocation.

We recommend translocating clumps rather than individual pads during future translocation efforts, even though the former is more labor intensive. Because removal of established clumps from a source population constitutes more of an adverse impact than the removal of pads, we suggest collecting pads and propagating them into small clumps with established roots prior to outplanting, a technique that has been implemented successfully at the Wind Wolves Preserve (Clendenen and Erickson 2013). Measures that could improve the success rate include choosing larger, heavier pads for propagation; collecting pads during the winter when they have a greater moisture content; conducting translocations during the fall or early winter to take full advantage of winter precipitation; and providing supplemental water to outplanted cactus clumps during the summer, especially following growing seasons with below-average precipitation. Nonetheless, we recommend that any future efforts to establish populations of Bakersfield cactus begin with much higher numbers of small clumps to compensate for potential mortality.

Genetic considerations also may influence the number of individuals used to establish a new population. Combining material from multiple source populations has been suggested as a means to increase genetic diversity during establishment of new populations (Godefroid et al. 2011). However, only one study (Smith 2013) has been conducted on the population genetics of Bakersfield cactus, and until more is known about whether genetic diversity is limiting for this species and whether local adaptation has occurred, we caution against mixing material from multiple sources. Similarly, caution should be used before establishing new Bakersfield cactus populations outside of the historical range of the taxon. Either decision would require concurrence from federal and state agencies, and should occur only after consultation with the recovery team for this species and other experts.

We recommend that guards be installed at the time of translocation if the area is grazed by livestock. The cattle guards we used at the BLCA appear to have effectively allowed the translocated cactus to become established. Although cattle may damage unprotected cactus plants, cattle grazing may provide an overall benefit to Bakersfield cactus populations by facilitating pad dispersal and reducing competition from non-native grasses as well as the threat of wildfire (USFWS 1998, Cypher et al. 2011b). In natural populations where grazing has reduced the ground cover and exposed soil, some of the pads detached by hoof contact develop roots and produce new cactus plants (Cypher et al. 2014). Cattle guards are a solution that can protect newly translocated plants while reaping other benefits of cattle grazing; once the young plants grow beyond the guards, opportunities for dispersal would become available.

A number of other elements incorporated into our efforts will be important for any future translocations. Competing vegetation must be controlled both before and after transplanting. Source populations should be relatively large with evidence of reproduction. Recipient sites should be permanently conserved through ownership by a federal or state conservation agency, or protected by a conservation easement. In addition, the sites should be appropriately managed to reduce threats to cactus populations from non-native plants, fire, or external influences. Advance planning for establishment of new populations will be essential to determine the appropriate sources of genetic material, secure permits, allow for collection of pads when they have the greatest water content, and propagate pads into well-rooted clumps before outplanting.

Despite the short-term success of these efforts, this technique is not recommended as mitigation, and translocation should not be considered a substitute for minimization of project impacts or protection of occupied habitat (Fielder 1991, Howald 1996). Translocation and introduction are best viewed as potential strategies for remediating habitat fragmentation within the range of Bakersfield cactus, which could contribute substantially to the conservation and ultimate recovery of Bakersfield cactus. Indeed, recovery of Bakersfield cactus, as defined in the recovery plan for this species (USFWS 1998), may already be precluded due to continuing habitat loss. Nevertheless, translocation and establishment of Bakersfield cactus on permanently conserved and appropriately managed sites could substantially advance conservation and recovery of this species.

Acknowledgments

Funding for this project was provided by the U.S. Bureau of Reclamation, South Central California Area Office and the Central Region of the California Department of Fish and Wildlife. We thank S. Heitkotter, A. Madrid, E. Tennant, and T. Westall for field assistance; S. Phillips for map preparation; the Center for Natural Lands Management and Johnston Farms for permission to collect Bakersfield cactus; the California Department of Fish and Wildlife and the Kern County Waste Management Department for their collaboration and willingness to host translocated Bakersfield cactus populations; N. Gruenhagen, D. Kelly, M. Kinsey, M. A. Showers, K. Tomlinson, and G. Warrick for administrative assistance; and D. Rogers, B. Warne, and an anonymous reviewer for their helpful suggestions.

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Received 27 December 2013
Accepted 18 February 2014
Corresponding Editor was C. Burton