FINAL REPORT

Preliminary Study to Determine the Effect of Nonnative Grasses on the Survival and Reproduction of Bakersfield Cactus

Submitted to:
John Thomson
Conservation Program Manager
U.S. Bureau of Reclamation, Sacramento, CA
and
Michael Kinsey
Senior Staff Biologist
U.S. Bureau of Reclamation, Fresno, CA

Submitted by:
Ellen Cypher and Craig Fiehler
California State University, Stanislaus
Endangered Species Recovery Program
1900 N. Gateway Blvd., Suite 101
Fresno, California 93727

September 12, 2006

ABSTRACT: Competition from nonnative grasses poses a potential threat to the endangered Bakersfield cactus (*Opuntia basilaris* var. *treleasei*) in the San Joaquin Valley, California. From 2002 through 2004 we investigated the effects of grass clipping and herbicide treatments on Bakersfield cactus survival, growth, flower production, and recruitment. Removal of nonnative grasses significantly improved the survival and growth of Bakersfield cactus but did not affect flower production or recruitment. The grass-specific herbicide Fusilade II was more effective for grass control and more beneficial for Bakersfield cactus health than clipping. Grass removal improved the growth of native forbs but also facilitated the invasion of two aggressive, nonnative forbs. Reducing competition from nonnative grasses could benefit Bakersfield cactus populations. However, any large-scale use of herbicide to benefit Bakersfield cactus must be accompanied by control of undesirable broad-leaved herbs.

INTRODUCTION

The introduction and widespread dominance of nonnative (nonnative) plants have greatly altered the composition of California grasslands and shrublands (Heady 1977, Mooney et al. 1986). Growth habits of nonnatives may differ considerably from natives. Nonnative grasses grow in more dense swards and leave behind more residual dry matter (i.e., mulch) than do natives. Under certain conditions of temperature and moisture, nonnative annual grasses germinate earlier than native grasses and forbs (Martens et al. 1994). The effect of these compositional changes on rare, native plants is unknown but is hypothesized to be detrimental through (1) physical inhibition of germination or growth by mulch, (2) competition for water and nutrients, and (3) changes in the frequency and intensity of wildfires.

Bakersfield cactus (*Opuntia basilaris* var. *treleasei*) is included on both the Federal and California lists of endangered species, primarily due to habitat loss. Nonnative grasses pose an ongoing threat to the remaining populations, including those in conservation ownership. The nonnative species compete directly with Bakersfield cactus for moisture and nutrients. In addition, nonnative grasses are thought to have several indirect effects on Bakersfield cactus, including harboring insect pests and decay organisms and also increasing the fire frequency (U.S. Fish and Wildlife Service 1998). This study was undertaken to determine whether removal of nonnative grasses would improve the growth, reproduction, and survival of Bakersfield cactus.

Study species

Bakersfield cactus is a type of beavertail cactus (platyopuntia) that is endemic to central Kern County, California. As with other beavertail cacti, Bakersfield cactus is a shrubby plant with flattened, succulent branches (pads) and very short-lived, inconspicuous leaves. The fruits are a dry type of pricklypear. The presence of long spines in the areoles and geographic range differentiate this taxon from other California beavertail cacti (Parfitt and Baker 1993). Flowering occurs annually, typically in May, but seed production is low and weather conditions in the area are rarely suitable for seed germination (Benson 1982). Vegetative reproduction is more common and occurs by rooting of fallen pads. Individual Bakersfield cactus plants are not easily identifiable because many stems can grow in close proximity and fallen pads can produce multiple stems, resulting in large concentrations ("clumps") originating near the same point.

METHODS

Study area

This study was conducted at the Sand Ridge Preserve, approximately 24 km east of Bakersfield in Kern County, California (Figure 1). It is located on the Edison 7.5' quadrangle, in Township 30S, Range 30E, Section 19. The Center for Natural Lands Management currently administers the 111-hectare preserve, which was acquired to protect the endangered Bakersfield cactus and the associated natural community with its diverse wildflowers. Elevations in Sand Ridge Preserve range from approximately 200 m on the Caliente Creek floodplain to 270 m on the ridgetop.

Aeolian sand deposits formed Sand Ridge, which lies northwest of the Caliente Creek floodplain. The natural community at Sand Ridge is a diverse, low-density shrubland with a ground cover of grasses and forbs; it has been characterized as Sierra-Tehachapi Saltbush Scrub (Griggs et al. 1992). Among the shrub species present are all-scale saltbush (*Atriplex polycarpa*), Mormon tea (*Ephedra californica*), bladderpod (*Isomeris arborea*), and mountain bush sunflower (*Encelia actoni*). The nonnative grasses ripgut brome (*Bromus diandrus*) and red brome (*Bromus madritensis* ssp. *rubens*) dominate in some sections of the preserve, whereas the nonnative forbs Sahara mustard (*Brassica tournefortii*) and shortpod mustard (*Hirschfeldia incana*) dominate in others. A variety of native, annual forbs persist on Sand Ridge, including lupines (*Lupinus* spp.), phacelias (*Phacelia* spp.), fiddleneck (*Amsinckia* spp), Coulter's jewelflower (*Caulanthus coulteri*), and Kern tarplant (*Deinandra pallida*).

The local climate is Mediterranean, with cool, moist winters and hot, dry summers (Major 1977). Precipitation in the Bakersfield area falls almost exclusively as rain. Annual precipitation at Bakersfield averaged 16.48 cm for the period 1971 to 2000 (Western Regional Climate Center 2005). The typical growing season for annual plants is between October and April, when the majority of rain (14.99 cm) falls. Rainfall during the course of the study was below average, totaling 8.66 cm, 14.66 cm, and 11.53 cm from October to April of 2001-2002, 2002-2003, and 2003-2004, respectively.

Treatments and cactus response

The response of Bakersfield cactus to two methods of grass removal, clipping and application of the grass-specific herbicide Fusilade II (fluazifop-p-butyl), was evaluated relative to unmanipulated controls. Twenty-five replicates were used per treatment. All plots were located on the upper elevations of the ridge (approximately 244 to 256 m), on a variety of exposures. Criteria for plot selection were that (1) the clump of Bakersfield cactus was confined within the plot boundary, (2) other than the Bakersfield cactus, nonnative grasses were dominant, and (3) plot centers were separated by at least 4.5 m. Clipped and control plots were established in February 2002, with treatment assigned randomly. Due to permit constraints, herbicide plots were not established until January 2003. Herbicide plots were interspersed among the existing

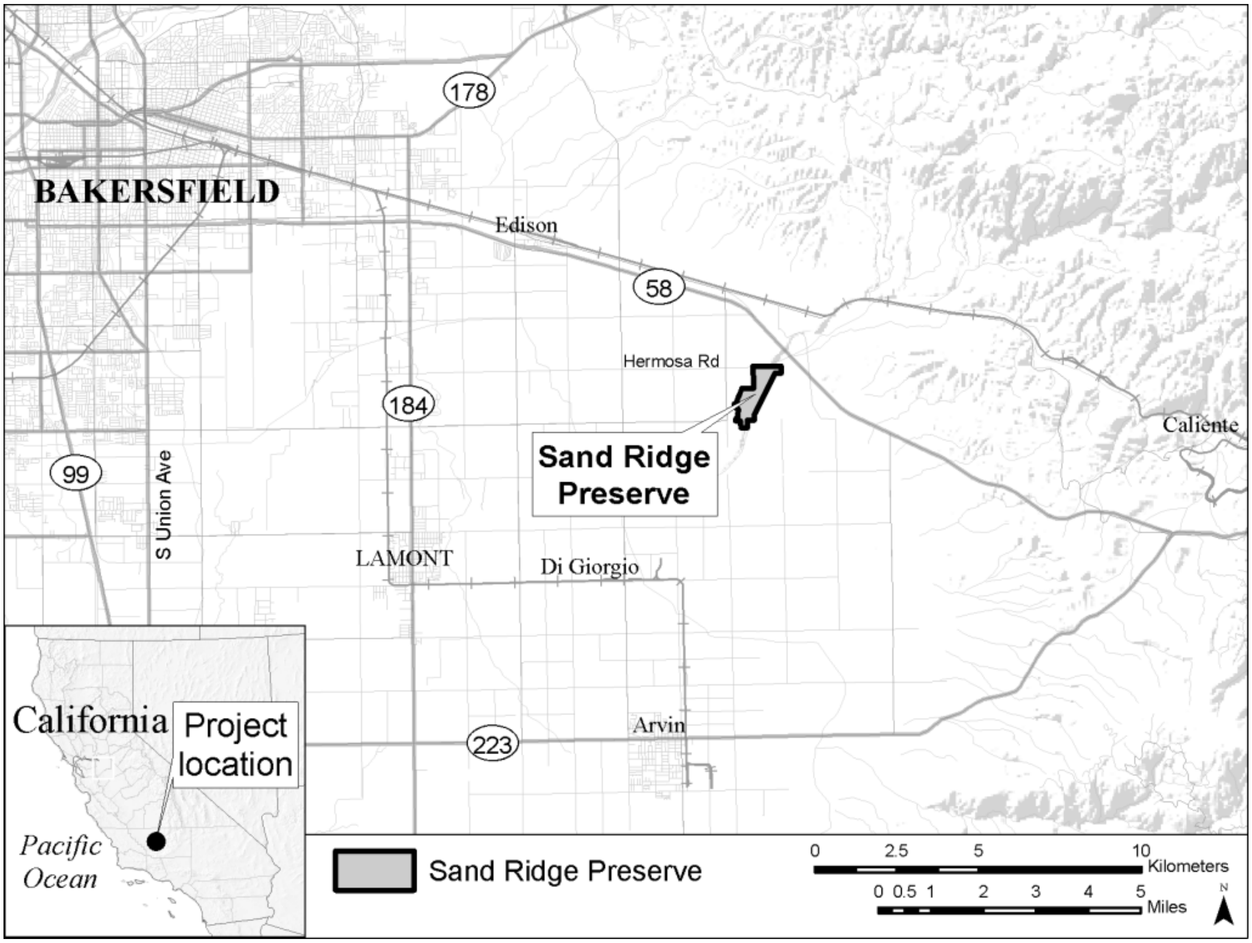

Figure 1. Location of the study area in Kern County, California.

plots, matched as closely as possible to control plots in number of cactus pads and associated species composition, and met the same selection criteria.

On the clipped plots and a 0.5-m buffer surrounding each one, all herbaceous vegetation was removed in February 2002, January 2003, and January 2004. Scissors were used to clip all herbaceous plants within 15 cm of Bakersfield cactus stems and an electric trimmer was used from that point out to the edge of the buffer. Grasses were clipped as close to the ground as possible without disturbing the soil, and clippings were removed from the site. Hand clipping of grasses only was repeated in February and March of each year to avoid disturbing associated forbs.

An herbicide treatment was added in January 2003 after a pilot study demonstrated that Fusilade II applied at 10% of the recommended concentration was not likely to harm Bakersfield cactus but was effective in killing the local nonnative grass species (E. Cypher, unpublished data). A backpack sprayer was used to apply Fusilade II at a rate of 0.13 ml active ingredient per m^2 mixed with water and surfactant. Each herbicide plot and a 0.5-m buffer around it was treated in January 2003 and again in January 2004.

The location, number, and baseline condition of living Bakersfield cactus pads in all study plots were recorded prior to treatment each year. Pad vigor was categorized as either healthy (turgid) or unhealthy (wrinkled or yellowed). The number of pads damaged by herbivory since the previous visit was recorded, along with the frequency of damage among plots; damage caused by insects was not differentiated from that of mammalian herbivores. After Bakersfield cactus completed flowering for the season (May or June), cactus condition was again recorded in all plots, along with the numbers of living pads, new pads produced, newly rooted pads (vegetative reproduction), and flowers produced (sexual reproduction).

Associated species composition

In April 2003 and 2004, absolute cover was estimated by plant species on all plots to assess the relative effectiveness of the treatments in removing nonnative grasses as well as treatment effects on other plants. Absolute cover was estimated again in 2005 to determine if a carryover effect was noticeable in the year following the last treatment. Cover data for all years were combined over three guilds (nonnative grasses, nonnative forbs, and native forbs) prior to statistical analysis. Native grasses were not present in any study plots; the one native monocotyledon was included with native forbs for analysis.

Statistical analyses

Cumulative net growth of Bakersfield cactus was calculated as the change in the number of live pads over 3 years for control and clipped treatments and over 2 years for the herbicide treatment. Quantitative data were analyzed via analysis of variance (ANOVA) after removing one data point to obtain a normal distribution. Frequency data were analyzed via contingency table analysis; the likelihood ratio Chi-square value was used for determining statistical significance except in the case of two-by-two contingency tables, in which case the Yates corrected Chi-square value was used. The acceptable type I error rate for all statistical tests was 5%, and all tests were two-tailed.

RESULTS

Cactus response

Cumulative net growth of Bakersfield cactus was higher when competing vegetation was removed (Figure 2). Average cumulative net growth was significantly lower in the control plots than in the clipped and herbicide plots where nonnative grasses had been removed (ANOVA F = 9.520, $P < 0.001$). The number of plots with cacti producing at least one flower did not differ by treatment between 2003 and 2004 ($\chi^2 = 5.39$, df = 2, $P = 0.07$). The number of plots that produced at least one new clump did not differ by treatment between 2003 and 2004 ($\chi^2 = 3.34$, df = 2, $P = 0.19$). By 2005, Bakersfield cactus had died out on five control plots but was still present in all clipped and herbicide plots.

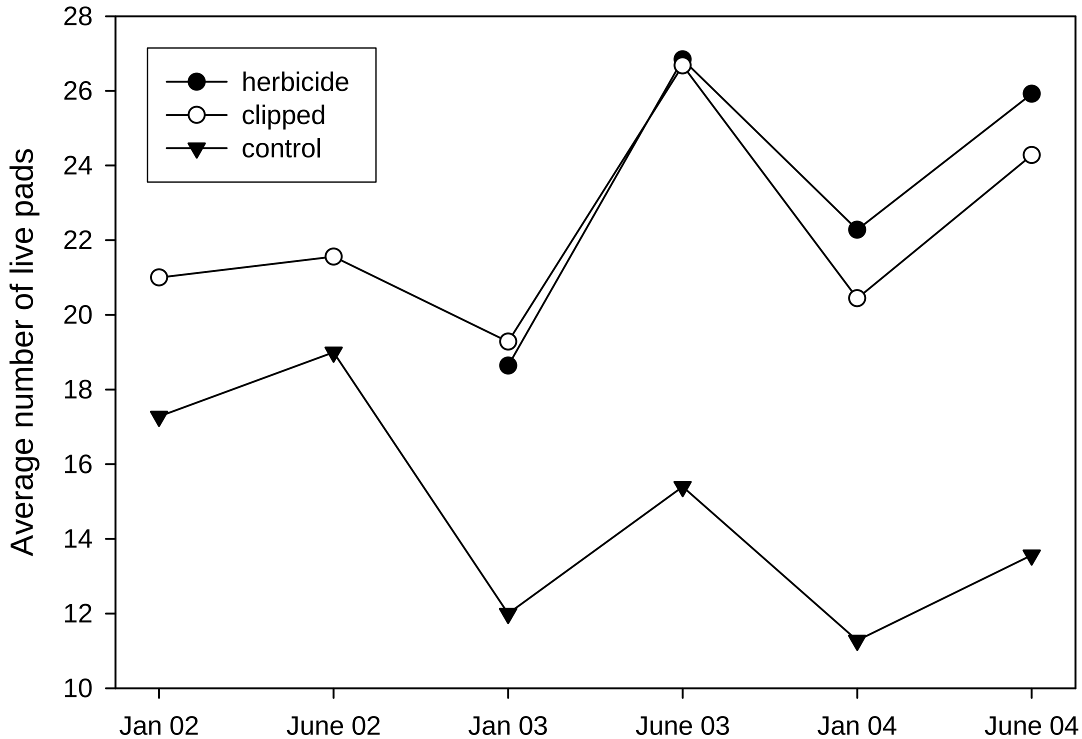

Figure 2. Mean plant size of Bakersfield cactus with and without competition at Sand Ridge Preserve from January 2002 to June 2004.

Associated species composition

Mean percent cover of native forbs, nonnative grass, and nonnative forbs differed significantly by treatment in 2003, 2004, and 2005, with the exception of nonnative forbs in 2005 (Table 1). We observed a carryover effect of the treatments on the plots, with mean percent cover of native grasses remaining low on the clipped and herbicide plots and high on the control plots for more than one year following the last treatment (Table 1). Species richness by guild was similar across treatments and across years, although fewer species were observed during the dry year of 2004. Herbicide-treated plots contained at least as many native species as did control plots throughout the course of the study (Table 2). We first detected the aggressive, nonnative forbs Sahara mustard and Russian thistle (*Salsola tragus*) in plots in 2003 and they appeared in additional study plots in succeeding years.

Table 1. Mean percent cover (± SE) for three guilds of associated plants on study plots. Values followed by the same letter are not significantly different.

Guild	n	Control	Clipped	Herbicide	*F*	*P*
2003						
Native forbs	25	$8.56 \pm 1.02_A$	$24.03 \pm 1.72_B$	$20.38 \pm 1.40_B$	32.83	< 0.001
Nonnative grasses	25	$47.32 \pm 4.22_A$	$1.08 \pm 0.22_B$	$0.30 \pm 0.20_B$	121.53	< 0.001
Nonnative forbs	25	$0.62 \pm 0.29_A$	$3.34 \pm 1.00_B$	$0.60 \pm 0.27_A$	6.42	0.003
2004						
Native forbs	25	$8.84 \pm 1.46_A$	$27.68 \pm 2.63_B$	$31.40 \pm 3.25_B$	22.40	< 0.001
Nonnative grasses	25	$66.58 \pm 3.03_A$	$6.04 \pm 1.25_B$	$2.00 \pm 0.93_B$	337.92	< 0.001
Nonnative forbs	25	$0.48 \pm 0.22_A$	$10.08 \pm 1.87_B$	$3.20 \pm 1.43_A$	13.13	< 0.001
2005						
Native forbs	25	$10.24 \pm 1.99_A$	$27.84 \pm 2.37_B$	$28.10 \pm 2.63_B$	19.09	< 0.001
Nonnative grasses	25	$84.76 \pm 2.25_A$	$13.64 \pm 3.13_B$	$15.40 \pm 3.56_B$	179.05	< 0.001
Nonnative forbs	25	$0.88 \pm 0.63_A$	$2.68 \pm 0.72_A$	$4.36 \pm 1.96_A$	1.91	0.155

Table 2. Species richness by guild. Native grasses were not present in any plots; monocotyledon wildflowers are included with forbs. Bakersfield cactus is not included in tallies.

	Nonnative grass	Nonnative forb	Native forb	Total species
2003				
Clipped	3	4	11	18
Control	3	2	13	18
Herbicide	2	5	13	20
2004				
Clipped	3	3	8	14
Control	2	1	5	8
Herbicide	3	4	10	17
2005				
Clipped	4	3	14	21
Control	2	3	6	11
Herbicide	4	6	12	22

Cactus condition

The proportion of healthy pads per plot did not differ among treatments in 2002 (P = 0.522) or 2004 (P = 0.314). In 2003, treatments differed significantly (P = 0.033), with a greater proportion of healthy pads in herbicide-treated plots (median = 83.3%) than in clipped plots (median = 68.8%), but neither differed from controls (median = 77.8%).

The treatments did not differ in proportion of pads damaged by herbivores in any year of the study (2002, P = 0.709; 2003, P = 0.302; 2004, P = 0.842). Median damage ranged from a low of 1.7% in 2002 to a high of 14.3% in 2003. Similarly, the frequency of damage did not differ among treatments (2002, P = 1.000; 2003, P = 0.174; 2004, P = 0.659).

DISCUSSION

When surrounding nonnative grasses were removed manually or chemically, growth of Bakersfield cactus increased dramatically. We documented net increases in the number of live pads and in the percent cover of Bakersfield cactus on the treated plots during the three growing seasons of 2002 through 2004. Therefore, competition with nonnative grasses is a critical component of the survival and growth of the Bakersfield cactus in this habitat. Native plants have been found to respond favorably to the removal or reduction of nonnative annual grasses that compete for aboveground and belowground resources (Gordon et al. 1989, Dyer and Rice 1999, Noy-Meir and Briske 2002). Burger and Louda (1994) also found that another platyopuntia, brittle pricklypear (*Opuntia fragilis*), grew significantly larger when released from competition with grasses. Our results are consistent with previous studies and indicate that Bakersfield cactus can compete successfully for resources under management regimes that include removal of nonnative competitors.

Removal of competing vegetation did not affect flower production or recruitment (new clumps) in the second and third seasons of the study. Overall, sexual and vegetative reproduction were low across treatments and years. Removal of competing nonnative grasses has been found to increase reproductive output in a native forb (Pavlik et al. 1993) and a native bunchgrass (Dyer and Rice 1999). Bowers (1996) found that higher soil moisture content increased flower development in another platyopuntia, Engelmann's pricklypear (*Opuntia engelmannii*). Although nonnative grasses were removed in this study, competition for soil moisture with forbs along with factors outside the growing season may have contributed to the low rates of sexual and vegetative reproduction in the Bakersfield cactus.

We observed a net decline in the number of cactus pads in control plots over a three-year period. The number of individual pads present in control plots during May 2004 was only 80.1% of the February 2002 count, and additional pads certainly died the following summer or winter, as evidenced by the disappearance of Bakersfield cactus from three additional plots. In contrast, the number of pads in clipped plots increased by 28.1% between February 2002 and May 2004. Although the number of pads in herbicide-treated plots was tracked only from January 2003 to May 2004 and therefore is not directly comparable, it showed an increase of 42.7% during that time. Recovery of Bakersfield cactus requires that all populations be stable or increasing (U.S.

Fish and Wildlife Service 1998). Thus, active management will be necessary to maintain population size, at least in years of below-average precipitation.

Bakersfield cactus died out completely on five control plots by May 2005. Mortality of Bakersfield cactus did not occur during the growing season, when competition from nonnative grasses would be expected to reduce moisture availability. Instead, the effects of reduced moisture storage become evident during or after the summer drought. July and August are the driest months of the year in the Bakersfield area, with average rainfall of 0.00 and 0.20 cm, respectively, over a 30-year period (Western Regional Climate Center 2005). June and September are the third and fourth driest months, respectively, with averages of 0.30 and 0.38 cm of precipitation. During the course of this study the summer months were drier than average, with no measurable precipitation between June 1 and September 30 in either 2002 or 2004 and only 0.23 cm total for the same period in 2003.

The timing of data collection in this study did not allow determination of the relative mortality during the dry season versus the frost season. Frosts are most likely during the months of December and January in the Bakersfield area (Western Regional Climate Center 2005). Frost is the primary mortality factor among cacti, although some *Opuntia* species do tolerate below-freezing temperatures (Benson 1982). The response of Bakersfield cactus to frost has not been investigated.

As demonstrated by estimates of species composition by guild, Fusilade II provided better control of grasses than clipping and was more cost-effective. Both the herbicide and the clipping provided considerable residual control into the following year, despite above-average rainfall.

Another potential threat to Bakersfield cactus posed by dense nonnative grasses would be creation of conditions favorable for the growth of decay organisms (U.S. Fish and Wildlife Service 1998).   Decay would be most likely in years of above-average precipitation or prolonged fog, which did not occur during the course of this study. Although damage due to herbivory was noted during this study, decay was not observed. However, precipitation was at or below average during the 3 years of this project.

Management implications

Weather conditions apparently affected the amount of competition in the plots and therefore the magnitude of treatment effect. In 2003, the year with the wettest growing season, herbicide plots fared significantly better than clipped plots in terms of new Bakersfield cactus clumps established and health of existing pads. However, even in drier years and under other factors of cactus condition and demography, Bakersfield cactus was at least as healthy in herbicide plots as in clipped plots. Considerable grass growth occurred in clipped plots during the 1-month intervals between clipping treatments, and thus clipping did not completely eliminate competition. Conversely, grasses were completely killed by a single treatment with herbicide in almost all plots. Thus, treatment with Fusilade II is recommended in preference to clipping or related techniques (e.g., mowing, grazing).

With judicious use, grass-specific herbicide can be useful for management of Bakersfield cactus habitat, but annual application of grass-specific herbicide is not recommended for several reasons. First, repeated herbicide exposure could be detrimental to Bakersfield cactus, even though short-term exposure was not. The manufacturer notes that up to 20% phytotoxicity is possible for pricklypear types of *Opuntia* when Fusilade II is applied at label rates (Syngenta Crop Protection, Inc. 2004). Second, repeated exposure to grass-specific herbicides may lead to selection of herbicide-resistant biotypes (Syngenta Crop Protection, Inc. 2004). Third, any native grasses in the spray area would likely be killed. A reasonable approach to grass control in Bakersfield cactus habitat would be to (1) use only a 10% concentration of Fusilade II to minimize the potential for phytotoxicity, (2) limit herbicide application to once every 2 or 3 years, and (3) avoid spraying patches of native grass.

The use of grass-specific herbicide seemed to improve both vegetative and sexual reproduction of Bakersfield cactus and to be preferable to hand clipping of grasses. Bakersfield cactus died out completely from five control plots during the course of the study but did not disappear from any treated plots. Native forbs dominated in the clipped and herbicide-treated plots, whereas nonnative grasses dominated in the control plots. The only potential drawback observed was that the broad-leaved, nonnative weeds Sahara mustard (*Brassica tournefortii*) and Russian thistle (*Salsola tragus*) became established in plots where grasses had been removed (through either clipping or use of grass-specific herbicide) but not in those dominated by grasses. Thus, grass control to benefit cactus would have to be accompanied by targeted control of these and other aggressive broad-leaved weeds.

One application of this research would be for creating a buffer free of nonnative grasses around Bakersfield cactus clumps prior to prescribed burns. Spring burns are one of the accepted methods for controlling *Bromus* species in wildlands (Brooks 2000, Young 2000), and prescribed fire has been used for management at Sand Ridge Preserve. Although the majority of Bakersfield cactus clumps have been shown to survive both spring and autumn wildfires, those that are surrounded by nonnative grasses become browned and wilted and do not flower the following year. Instead, burned clumps invest their resources in pad production (Hewett in litt. 1987, Lawrence 1987, George Lawrence and Associates 1988). A mowed buffer is effective in protecting Bakersfield cactus clumps (Hewett in litt. 1987), but mowing would be inadvisable where many cactus clumps grow in close proximity. By applying Fusilade II in the winter prior to a planned spring burn, a safe zone could be created around clumps of Bakersfield cactus to protect the plants from direct fire effects. Although forbs would be present in the treated zone, the fuel load would likely be less than with nonnative grasses, reducing fire intensity near the cactus. Manual control of Sahara mustard would be necessary in the herbicide-treated zone, because that species can generate enough fuel to carry a fire (Minnich and Sanders 2000).

The lack of a difference in herbivory among treatments indicates that management to remove nonnative grasses would not lead to increased pad damage. This is consistent with a study of insect herbivory on brittle prickly pear (*Opuntia fragilis*), a beavertail cactus from the Sandhills of western Nebraska. In that study, a moth larva (*Melitara dentata*) was the primary source of mortality among cactus pads. The moth larvae were less likely to feed on cactus in areas where grass had been removed than in grassy or shaded areas. Conversely, a sucking bug (*Chelinidea vittiger*) occurred more frequently in areas where grass had been removed than elsewhere

(Burger and Louda 1994). Herbivory by sucking insects most likely would have manifested as unhealthy condition (e.g., wrinkled pads) in this study rather than damage because the latter was defined as visible breaks in the epidermis or removal of pieces of tissue. Cactus health differed only in the wettest year of the study (2003), in which herbicide-treated plots exhibited healthier condition than clipped plots. Thus, sucking bugs may not be a problem in the range of Bakersfield cactus.

We do not expect that judicious use of herbicide to remove nonnative grasses will cause detrimental effects on the plant community as a whole. The high species richness over three years, especially among native plants, indicated that the herbicide did not favor Bakersfield cactus at the expense of other native plants. Combined with targeted control of invasive plants, herbicide treatment can be an effective tool for managing nonnative grasses in Bakersfield cactus habitat.

ACKNOWLEDGMENTS

The Central Valley Project Conservation Program, a joint effort between the U.S. Bureau of Reclamation and the U.S. Fish and Wildlife Service, provided the funding for this research. The Center for Natural Lands Management graciously allowed the use of the Sand Ridge Preserve, and preserve manager Greg Warrick assisted with herbicide application, clipping, and data collection. Thanks to Dr. Sam Behseta for statistical advice. Special thanks to Justin Brown and Jessica Huddleston for many hours spent hand-clipping grasses as well as data collection. Other Endangered Species Recovery Program employees and volunteers who assisted with clipping and data collection were Alexander Brown, Stephen Harrison, Graciela Hinshaw, Xiaohong Huang, Emily Orling, and Erin Tennant. Mary Ann McCrary, then regional botanist with the California Department of Fish and Game, contributed to the design of this study.

LITERATURE CITED

Benson, L.D. 1982. The cacti of the United States and Canada. Stanford Univ. Press, Stanford, CA, 1044 pp.

Brooks, M.L. 2000. *Bromus madritensis* ssp. *rubens* (L.) Husnot. Pages 72-76 *in* Invasive plants of California's wildlands (C.C. Bossard, J.M. Randall, and M.C. Hoshovsky, editors). University of California Press, Berkeley, 360 pp.

Bowers, J.E. 1996. Growth rate and life span of a prickly pear cactus, *Opuntia* engelmannii, in the northern Sonoran Desert. The Southwestern Naturalist 41(3):315-318.

Burger, J.C., and S.M. Louda. 1994. Indirect versus direct effects of grasses on growth of a cactus (*Opuntia fragilis*): insect herbivory versus competition. Oecologia 99:79-87.

Dyer A. R. & K. J. Rice. 1999. Effects of competition on resource availability and growth in a native bunchgrass in two California grasslands. Ecology 80:2697-2710.

George Lawrence and Associates. 1988. A biological assessment: Rio Bravo rare cactus report. U.S. Fish and Wildlife Service, Sacramento, CA, Unpubl. Rep., 20 pp.

Gordon D.R., J.M. Welker, J.W. Menke, and K.J. Rice. 1989. Competition for soil water between annual plants and blue oak (*Quercus douglasii*) seedlings. Oecologia 79:533-541.

Griggs, F.T., J.M. Zaninovich, and G.D. Werschkull. 1992. Historic native vegetation map of the Tulare Basin, California. Pp. 111-118, *in* Endangered and sensitive species of the San Joaquin Valley, California: their biology, management, and conservation (D.F. Williams, S. Byrne, and T.A. Rado, eds.). California Energy Commission, Sacramento, 388 pp.

Heady, H.F. 1977. Valley grassland. Pages 491-514 *in* Terrestrial vegetation of California (M.G. Barbour and J. Major, editors). California Native Plant Society Special Publication Number 9, Sacramento, CA, 1002 pp.

Hewett, R. 1987. Letter from Sand Ridge Preserve Manager, Weldon, CA., to James J. McKevitt, U.S. Fish and Wildlife Service, Sacramento, CA, 2 pp.

Parfitt, B.D., and M.A. Baker. 1993. Opuntia; prickly-pear, cholla. Pages 452-456 *in* The Jepson manual: higher plants of California (J.C. Hickman, ed.). University of California Press, Berkeley, 1400 pp.

Lawrence, G. 1987. A status report - Rio Bravo hydroelectric site grass fire impact on - rare cactus. Unpubl. Rep., Borcalli, Ensign, and Buckley, Consulting Engineers, Sacramento, CA, 5 pp.

Major, J. 1977. California climate in relation to vegetation. Pages 11-74 *in* Terrestrial vegetation of California (M.G. Barbour and J. Major, editors). California Native Plant Society Special Publication Number 9, Sacramento, CA, 1002 pp.

Martens, E., D. Palmquist, and J.A. Young. 1994. Temperature profiles for germination of cheatgrass versus native perennial bunchgrasses. Pp. 238–243 *in* Proceedings—Ecology and management of annual rangelands (S.B. Monsen and S.G. Kitchen, editors). U.S. Department of Agriculture Forest Service, Intermountain Research Station, General Technical Report INT-GTR-313.

Minnich, R.A., and A.C. Sanders. 2000. *Brassica tournefortii* Gouan. Pages 68-72 *in* Invasive plants of California’s wildlands (C.C. Bossard, J.M. Randall, and M.C. Hoshovsky, editors). University of California Press, Berkeley, 360 pp.

Mooney H.A., S.P. Hamburg, and J.A. Drake. 1986. The invasions of plants and animals into California. Pages 250–272 *in* Ecology of biological invasions of North America and Hawaii (H.A. Mooney and J.A. Drake, editors). Springer-Verlag, New York, 321 pp.

Noy-Meir, I., and D.D. Briske. 2002. Response of wild wheat populations to grazing in Mediterranean grasslands: the relative influence of defoliation, competition, mulch and genotype. Journal of Applied Ecology 39:259-278.

Pavlik, B.M., D.Nickrent and A. Howald. 1993. The recovery of an endangered plant. I. Creating a new population of *Amsinckia grandiflora*. Conservation Biology 7:510-526.

Syngenta Crop Protection, Inc. 2004. Fusilade II label. Greensboro, NC.

U.S. Fish and Wildlife Service. 1998. Recovery plan for upland species of the San Joaquin Valley, California. Region 1, Portland, OR. 319 pp.

Western Regional Climate Center. 2005. Monthly precipitation listings for Bakersfield, California. <http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?cabake+sca >.

Young, J. 2000. *Bromus tectorum* L. Pages 76-80 *in* Invasive plants of California's wildlands (C.C. Bossard, J.M. Randall, and M.C. Hoshovsky, editors). University of California Press, Berkeley, 360 pp.

Photographs

Representative control (unmanipulated) plot in May 2004.

Representative clipped plot in May 2004.

Representative herbicide-treated plot in May 2004.

Herbicide-treated plot in May 2004 containing the non-native Sahara mustard (*Brassica tournefortii*) in addition to Bakersfield cactus. The green plant growing in the sprayed buffer area adjacent to the plot is the non-native short-pod mustard (*Hirschfeldia incana*).

Contact

The primary contact on this report is:

Dr. Ellen Cypher
California State University, Stanislaus
Endangered Species Recovery Program
P.O. Box 9622
Bakersfield, CA 93389-9622
Phone: (661) 398-2201
Fax: (661) 827-1992
E-mail: ecypher@esrp.csustan.edu