EFFECTS OF FIRE ON KUENZLER'S HEDGEHOG CACTUS

(*ECHINOCEREUS FENDLERI* VAR. *KUENZLERI*)

Final report to the Joint Fire Science Program

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EXECUTIVE SUMMARY

Kuenzler's cactus (*Echinocereus fendleri* var. *kuenzleri* [Castetter, Pierce and Schwerin] L. Benson]) is a federally- and state-listed endangered species that is known to occur in pinyon-juniper habitat in the mountains of south central New Mexico in Lincoln, Otero, Chaves and Eddy counties. Presence of this species affects the management of its habitat with prescribed burning. However, there has been no research that has documented the response of Kuenzler's cactus to fire.

This project was initiated in 2002 to provide information on habitat characteristics of Kuenzler's cacti and to investigate its response to fire. Because of the protected status of the species, this report provides thorough documentation of correspondence with the U.S. Fish and Wildlife Service (USFWS) to acquire "take permits" to conduct our research.

Research was designed with two complementary components of study. Field work in Lincoln and Eddy Counties, New Mexico involved the location and marking of plants for study. These plants were described with respect to morphological characteristics and habitat features. Prescribed burning was conducted by exposing a 12-m^2 area surrounding plants to hand-ignited fire (n=13 burned plants in Eddy Co. and n=96 burned plants in Lincoln Co.). First- and second-year results indicated that burning did not affect frequency of flowering, number of flowers produced, or plant mortality.

Nursery-purchased plants were grown under greenhouse conditions for 2 years prior to use in a controlled-burning experiment that involved burning plants either with excelsior as a fine fuel source (at 600 or 1,200 lbs/acre, fuel loads that represent average and high fuel amounts in the plant's habitat in New Mexico) or in a burn barrel with

durations of flame of 5, 10 or 15 seconds. All plants burned in the burn barrel showed apparent mortality 3-months post burning. Plants burned with the equivalent of 1,200 lbs/acre of excelsior had higher mortality than plants burned with 600 lbs/acre of fuel or control plants, and there was no difference in mortality between control plants and plants burned with 600 lbs/acre of excelsior. There was a negative relationship between plant size and mortality of plants burned with the equivalent of 600 lbs/acre of fuel: smaller plants had a higher probability of mortality than larger plants. There was no relationship between mortality and plant size for plants burned with the equivalent of 1,200 lbs/acre of fuel.

Results of our field surveys provide strong indications that this plant is not as rare as previously thought. This information was used by the U.S. Fish and Wildlife Service in its 2005 "Five-Year Review" of this species.

Under the conditions of our field burning in New Mexico, we found no evidence that the species is negatively affected by burning. Early (3-month post burning) indications from plants burned under conditions of known and controlled fuel amounts and spatial distribution also suggest that under average fine fuel conditions, this species is not negatively affected by fire. However, smaller plants have a higher probability of mortality than larger plants. Our results also show that plants burned under conditions of high fuel loads experience increased mortality, and this is not related to plant size. Therefore, use of prescribed fire in habitats that include Kuenzler's cacti must be based on burn plans that take into account the amount of fuel.

INTRODUCTION

Discovery, Taxonomic Issues, and Status

Kuenzler's hedgehog cactus was originally discovered near Elk, New Mexico, in 1961, when the plant was "known under the unpublished name of *Echinocereus pseudohempelii*" (ESIS, 1996). In 1975, this name was changed to *E. hempelii*, and in 1976 the plant was renamed by Castetter et al. (1976) as *E. kuenzleri* after H. Kuenzler, its original discoverer. Currently, the plant is assigned the name *E. fendleri* var. *kuenzleri* [Castetter, Pierce and Schwerin] L. Benson]) (Kartesz, 1994), an assignment that Mellen (1991) attributed to Taylor (1985).

Kuenzler's cactus is currently listed as an endangered species by the U.S. Fish and Wildlife Service (*Federal Register*, 1979, Vol. 44, No. 209, pp. 61924-61927). This species was included in the July 19, 1975 "notice of review" as *E. hempelii*, and was proposed as endangered on June 16, 1978 under this name. At the State of New Mexico level, the status of this species is "G4G5T1" (G4: Apparently secure; G5: Secure; T1: critically imperiled at the infraspecific level); this status was assigned on 10 November, 1989; Natural Heritage Program, State of New Mexico, September 2007.

Description of the Plant

Kuenzler's cactus plants are generally simple (Fig. 1) but can be branched (Fig. 2) with conical stems 1 to 4 (and up to 8) in number. Plants generally reach heights of 7.5 to 15 cm (rarely 30 cm), and have 9 to 12 ribs lined with areoles. Each areole has 3 to 7 spines; additionally, the absence of a central spine is a distinguished characteristic of this

species. Kuenzler's cactus has the largest flower (magenta) and the fewest spines of *E. fendleri* or any of the *E. fendleri* varieties (Fig. 1). Kuenzler's cactus reproduces sexually when it reaches 4 to 5 years of age (Sivinski 1999), flowering in early May depending on climatic conditions.

Habitat Description

Kuenzler's cactus is thought to be endemic to south central New Mexico on the eastern slopes of the Sacramento, Capitan, and Guadalupe Mountains. More recent reports indicate the cactus has been found as far south as the state of Chihuahua, Mexico in the Santa Clara Valley (Melen, 1991). Plants occur between 1,830 and 2,130 m in elevation in juniper-pinyon woodlands (Castetter et al., 1976). Although plants are usually found on sloping sites (5 to 20% slope), they can also be found on hilltops and near bottom lands. Plants are often found in grass clumps or wedged against rocks: this pattern endorses a theory of thermal protection provided by its surroundings (DeBruin, 1996). Populations with "thriving [plants] and new recruits surviving" are reported to grow with at least 24% ground cover (DeBruin, 1996, p. 8).

Management Considerations

One management tool necessary for the pinyon-juniper habitat is fire (Wright and Bailey 1982). The pinyon-juniper and surrounding grassland habitats are subject to frequent lightning strikes during severe summer storms, contributing to a regular fire regime. Fire, occurring every 10 to 30 years on the average, has been a dominant force controlling the distribution of pinyon-juniper (Wilkerson 1997; Wright and Bailey 1982:198). Fire suppression and overgrazing has retarded natural fire occurrence

allowing for the encroachment of woody species in the neighboring grasslands (Wright and Bailey, 1982). This problem, as well as many treatment options, has been well documented (Wright and Bailey, 1982 and references therein; Paysen et al., 2000 and references therein).

The U.S. Bureau of Land Management (USBLM) Carlsbad and Roswell Field offices conduct prescribe fires throughout Kuenzler's habitat to reduce woody fuel loads and improve range conditions. However, little is known about Kuenzler's cactus response to fire, natural or prescribed. Because of the plant's endangered listing in 1979, fire management efforts have avoided large areas that may contain or are known to contain Kuenzler's cacti. Therefore, lack of knowledge of the response of Kuenzler's cacti to fire has limited management practices to total fire exclusion. It is unknown if fire has an impact on Kuenzler's cactus. Current exclusion and fire suppression practices limit land managers and do not improve native rangelands. When funding for this project was initiated in 2002, 25,000 hectares were removed from the USBLM Carlsbad Field Office prescribed fire plan because of the presence or possible presence of Kuenzler's cacti: protective policies at that time included implementing a 1.6-km buffer zone around Kuenzler's cacti habitat to be burned with prescribed fire. The Fort Stanton Area of Critical Environmental Concern Final Activity Plan states, "The full wildfire suppression response level will be applied at Fort Stanton to protect Kuenzler's cactus habitat…" (USDI BLM, 2001, p. 1-6). Without a more complete understanding of the effect of fire on Kuenzler's cactus, it is not possible to implement effective management strategies.

Objectives

This research investigates the habitat requirements and the effect of fire on Kuenzler's hedgehog cactus. Specific objectives include: (1) describe the micro- and macro-habitat characteristics of Kuenzler's cacti; (2) compare mortality between burned and non-burned cacti; and (3) relate cacti response to micro-environmental factors associated with fuel load and fuel arrangement.

To fulfill these objectives, this research was designed to include two components: (1) field research in New Mexico using plants in their natural habitat, and (2) research conducted in Lubbock, Texas using plants that had been grown under greenhouse conditions and burned under controlled conditions. These components are described more fully below.

METHODS

Field Research on Plants in the Natural Habitat in New Mexico

USBLM personnel proposed a number of known Kuenzler cactus populations thought to contain enough cacti to support a study. Four study sites were selected (Fig. 3). Field work was conducted at three sites in the Fort Stanton Special Area of Environmental Critical Concern in Lincoln County, New Mexico (Fig. 4) and at one site in western Eddy County, New Mexico (Fig. 5). Both areas are managed by the U.S. Bureau of Land Management. The three sites in the Fort Stanton area are approximately 15 km northwest of Ruidoso, New Mexico. These sites were named for their direction from the Ruidoso Regional Airport: NA (north of the airport), WA (west of the airport),

and SA (south of the airport). The site in Eddy County, New Mexico is approximately 52 km west of Carlsbad, New Mexico was named TX-HILL.

Issues with the U.S. Fish and Wildlife Service Regarding Number of Plants to be Included in this Research

The draft Biological Assessment by the USFWS (dated 24 November, 2002; Appendix A) indicated concern about the number of plants we wished to use in this research. We responded on 11 February, 2003 with documentation supporting our request (Appendix B). On 23 June, 2003 we engaged in telephone conversation with the USFWS, New Mexico Ecological Field Office about sample size issues. On 14 July, 2003, the USFWS provided a Biological Assessment for this project allowing for burning of 13 plants in the TX-Hill study area and 48 plants in the Fort Stanton study area; these numbers present 5% of the known populations in these areas (Appendix C). The USFWS also indicated that we would be allowed to use 5% of any additional plants we could locate that were not included in the currently-known populations (Appendices C, D).

Surveys were conducted throughout 2003 to find as many cacti as possible on all four sites. Each cactus found was assigned a number. Numbers were stamped on a metal tag held in place by a metal stake. The metal tags were made from galvanized roofing washers about 5 cm in diameter. Each washer had a 0.6 cm hole drilled in the middle, was painted fluorescent orange, and was stamped with a unique number. Metal stakes, 12 cm long, were driven into the ground through the middle of the numbered washer. This permanently marked each cactus. A GPS location, with a Trimble GeoExplorer 3, was taken of each cactus. GPS points were then downloaded into ERDAS Imaging and differentially corrected.

As a result of our survey work in 2003, we located an additional 556 plants in populations that were known to have 176 plants; additionally, we located a previously-unknown population that included 38 plants. We thus documented an increase of 338% in the numbers of known plants for these populations. Under the assumption that our sampling applied to the Fort Stanton population as a whole, we provided an estimate for this area of 4,148 plants. On 7 November 2003, we formally requested that we be allowed an additional 48 plants for our work in Fort Stanton (Appendix E). This request was granted on 19 November 2003 (Appendix F).

As a result, we conducted field work with 13 plants assigned to burn treatment at the TX-Hill study area (with an additional 13 plants assigned to a control treatment). At the Fort Stanton study area, we assigned 96 plants to be burned and used an additional 96 plants as controls; plants were assigned to the three study sites in proportion to the number of eligible cacti at each site: NA, 28 burned and 28 control cacti; SA, 16 burned and 16 control cacti; and WA, 52 burned and 52 control cacti.

Study Area Description

Lincoln County's climate varies because of topographic variability. Half of the annual precipitation falls during the summer in brief, isolated and often severe thunderstorms. In the eastern plains, annual precipitation is 28 to 33 cm which increases to about 50.8 cm at 2,100 m. Rainfall exceeds 63 cm in the higher mountains where winter snow averages 1.2 m. Mean annual temperatures range from at 14.4ºC at the lower elevation and to 8.8ºC in the mountains. The frost-free period for the mid-elevations is about 155 days. Diurnal temperatures usually vary more than 16ºC. Sunshine prevails 75% of the possible time (Houghton 1983).

Three sites were located in the Fort Stanton Special Area of Environmental Critical Concern between 1,980 m and 2,140 m in elevation. The major soil of sites that support the cacti at the Fort Stanton area is classified as a Romine extremely gravelly loam soil with 15 to 45 percent slopes. Other soils include: Hightower-Oro Grande complex, Pena-Dioxice complex, Plack-Dioxoce complex, Reventon loam, and Stroupe bouldery sandy clay loam. These soils are on sites that are flat to extremely steep. The plant community of the area is pinyon-juniper grassland. Blue grama (*Bouteloua gracilis*), sideoats grama (*Bouteloua curtipendula*), curl leaf muhly (*Muhlenbergia setifolia*), one-seeded juniper (*Juniperus monosperma*), pinyon pine (*Pinus edulis*), wavyleaf oak (*Quercus undulata*) characterize the plant community (USDA SCS 1983).

Eddy County has a semiarid continental climate. The mean annual temperature ranges from 15.5 to 17.7º C. The mean minimum temperatures are 6.6 to 9.4º C and the mean maximum temperatures are 23.8 to 26.1º C. Annual extremes can exceed 43.3º C in the summer and drop below -17.7ºC in the winter. The average annual rainfall in Eddy County can range between 25 to 61 cm. Approximately 80% of the precipitation is recorded between May and October. June, July, and August have frequent, isolated and severe thunderstorms, some of which bring hail. Average annual snowfall ranges from 7.6 to 20.3 cm. Evaporation rates are 254 to 280 cm per year. Skies are sunny about 75% of daylight hours (Houghton 1971).

The site in Eddy County, New Mexico is between 1,580 and 1,660 m in elevation. Common soils include an Ector stony loam, 0 to 9% slope, an Ector extremely rocky loam, 9 to 25% slope, and Limestone rock land. The plant community of the area is mainly grassland with scattered juniper. Blue grama (*Bouteloua gracilis*), sideoats grama

(*Bouteloua curtipendula*), curl leaf muhly (*Muhlenbergia setifolia*), one-seeded juniper (*Juniperus monosperma*), and agave (*Agave neomexicana*) dominate the plant community.

Prescribed Burns

Burning prescriptions were set by the USBLM. A drip torch was used for ignition. A line at least 3 m long was ignited at least 2 m from the target cactus. The ignited line was downhill, downwind, or a combination both in order to carry the fire over and beyond the target cactus. One plot was burned at a time. The plot was completely extinguished before igniting another plot. The burn was extinguished by USBLM personnel using backpack sprayers and hand tools.

Data Collection

Habitat Characteristics

Elevation, slope, and aspect data were recorded at each cactus. Elevation was taken from USGS 7.5 minutes maps. Slope was measured in degrees using a Johnson's® Magnetic Angle Locator no. 700. Aspect was recorded with a compass to the nearest 5º when facing the same direction of the slope.

Plots, 110 cm in diameter containing each cactus, were analyzed to describe the immediate habitat surroundings of Kuenzler cacti. The locations of these plots were marked by at least two 12 cm metal stakes in the ground. An aluminum tripod was constructed with a 110-cm diameter circle as the base. The base of the tripod represented the study plot and was constructed of 0.635 x 2.54 cm aluminum bar. Three legs were constructed of 1.905 x 1.27 cm aluminum bar. At the top of the legs, an aluminum

housing was machined to fit a digital camera fixed downward at the plot. The tripod housed a Canon A70 digital camera. The height of the lens, when placed in the tripod housing, was 173 cm above the ground. This was the shortest possible height for the Canon A70 to fit the entire base of the tripod in the frame. The circular base was placed to fit around the metal stakes in the ground, marking the plot location. This allowed repeatable pictures over time. Pictures were organized by date and plot and were viewable as a digital catalog. A hand-drawn map of the plot was drawn in the field to identify species in the photographed plot. All plants within 55 cm of the cacti were recorded in the hand-drawn map by species to identify plants in the digital photographs.

Foliar cover was measured using digital photographs, ERDAS Imaging, and ArcMap. Digital pictures were downloaded as .jpg files using Canon Utilities Zoom Browser EX Version 4.5. Pictures were labeled and organized by plot number, year, month, and day. ERDAS Imaging was used to convert the .jpg to an .img file. Pictures were imported into ERDAS, converted, and then saved. The .img files were brought into ARCMAP to make a map of the vegetation for each plot. Foliar cover was outlined digitally in ArcMap, creating a shapefile for each digital picture in a geodatabase. To outline foliar cover, a map was created that consisted of the digital picture and its corresponding shapefile. In the editing toolbar, Start Editing, was selected for the shapefile. Every polygon created represented an individual herbaceous or woody plant and added a line to a corresponding table that was automatically created when editing the shapefile. The table consisted of the following columns: ObjectID, Shape, SHAPE_Length, SHAPE_Area. Columns for species and percent area were added when creating the shapefiles. Plants were labeled by species in the table by referring to the

hand-drawn maps (see above). The area outlined represented a percentage of the entire area of the plot. This percent area was calculated by dividing the SHAPE_Area of a plant by the SHAPE_Area of the plot. Percent area was then translated into square centimeters.

Foliar cover was also measured for the 10 randomly located plots that did not contain an Kuenzler cactus. Herbaceous plants within these 10 plots were clipped. Each herbaceous plant clipped was placed in a paper bag and labeled by species and a unique number that was used to identify the plant's location on the hand drawn map of the plot. The plants were then dried and weighed. Each foliar area of a plant then had a corresponding dry weight. The relationship between foliar cover (cm^2) and dry weight (g) was estimated for each species using linear regression.

After establishing a method to estimate biomass of a given herbaceous plant, these shapefiles were then processed to describe the fuel arrangement in the whole plot (within 55 cm of the central Kuenzler's cactus), in an area within 28 cm of the cactus, and an area within 15 of the cactus. This description of biomass/fuel load at these 3 scales was used to analyze fuel arrangement in the microhabitat of Kuenzler cacti.

Cacti Characteristics

For each cactus, the following data were recorded: number of stems; height (on the uphill and downhill side) and diameter (at the base of each plant at the widest point) of each stem; and the length of longest and shortest axes at the base of the entire cluster. The number of stems was counted when cacti were first located. Cactus size was measured using the same technique used described in Data Collection (Habitat Characteristics section). Evidence of flower or fruit was recorded. Cacti were then

monitored monthly during the study period to verify how many flowers and fruits were produced per cactus per year. Nearest neighbor information was recorded by distance and species.

Prescribed Burns

The USBLM Carlsbad Field Office was responsible for the prescribed burns at the TX-Hill site which took place on April 19, 2004 and June 15, 2004. Cacti at TX-Hill were then monitored until October 2005. The USBLM Roswell Field Office was responsible for the burns at the NA, SA, and WA sites, which took place on 6 April, 12 March, and 3 and 12 March, 2005, respectively. Cacti at NA, SA, and WA sites were monitored until October 2005.

Air temperature, relative humidity, and wind speed were recorded with a Kestrel™ Pocket Wind Meter model K3000 before each plot was ignited. Weather data were also taken from the Ruidoso Regional Airport and Carlsbad City Airport weather history at 2 web sites; Weather Underground (www.wunderground.com) and National Oceanic and Atmospheric Administration (www.weather.gov).

Three to 5 soil samples of at least 5 g between the depths of 0 to 5 cm were collected at each cactus, just outside the plot to be burned. Samples were stored in tin containers and weighed. Samples were then oven dried at 105ºC until soil reached a constant weight. Dry weights were recorded and soil moisture was calculated.

Immediately after each cactus was burned, an infrared thermometer (Raytek® Raynger® ST) was used to measure the surface temperature of the burned cacti. The maximum temperature measured was recorded.

Data Analysis

Cacti Characteristics

Descriptive statistics were used to describe each Kuenzler cactus in the study. The average cactus size, average number of stems, percentage of cactus that flowered, and number of fruits and flowers per cacti were recorded. Each site was considered a population of interest. A completely randomized design was used to compare cactus characteristics among sites; a protected least significant difference (LSD) was used to separate site means (Steele and Torrie 1980). A Levene's test was used to detect differences in the variances of area, height, and number of stems.

Habitat Characteristics

Cactus habitat was partitioned into macro- and micro-habitat. The macro-habitat described the general characteristics of the four sites studied. The micro-habitat described the immediate surroundings of each Kuenzler cactus at 3 scales: within 55 cm, within 28 cm, and within 15 cm of each cactus.

Macro-habitat was summarized in a series of descriptive statistics. Elevation, slope, aspect, and biomass were described for each site.

Micro-habitat was summarized in a series of descriptive statistics at the 3 scales. Biomass, herbaceous foliar cover, and richness were described at each cactus at each site. Biomass of individual herbaceous plants was predicted using linear regression with foliar cover (cm^2) as the independent variable. Several possible functional relationships were used to estimate biomass (Fig. 6). Regression equations were estimated for each species at each site using all 5 models. The single best model for a species was chosen to predict

biomass for that species on that site. Model selection was based on the highest coefficient of determination and as well as models with an intercept closest to zero (to avoid negative estimates of biomass for plants with small area). Equations were based on clipping data from all sites to identify the best model for each species.

For biomass and cover the following tests were performed. The Shapiro-Wilk (Shapiro and Wilk 1965) test was used to test for a normal distribution of the experimental errors of each measurement at each site. Mauchly's (1940) test was used to test for sphericity of each measurement. If sphericity was violated and a difference between means was detected, an LSD test with an error term specific to each contrast was used (Kirk 1995).

Richness was described in each scale of measurement in the micro-habitat assessment. Observations were noted and descriptive statistics were completed at each scale at each site.

Burning Effects

At the TX-Hill site, cacti were monitored for 2 growing seasons post-burning. At the NA, SA, and WA sites, cacti were monitor for 1 growing season post-burning. Results of each site should be interpreted accordingly. Two responses were examined to determine effects of prescribed fire on Kuenzler's cacti: mortality and flowering/fruit production.

Obvious mortality was a visual measure in which cacti were completely shriveled and discolored, were consumed, or were detached from any buried roots. Plants were monitored monthly post-burning and recorded as dead or alive. A generalized linear

model was used to compare percent mortality of control cacti to burn cacti. Treatments were burn and control, and sites were blocks.

The second response variable was whether fire influenced the cactus' flowering/fruiting response after burning. Burned and control cacti were monitored to determine if a cactus flowered; the number of fruits and flowers per plant were recorded. For the TX-HILL site no pre-treatment data were collected. At the TX-HILL site a generalized linear model in a completely randomized design was used to analyze the percent difference of flowering cacti. A general linear model was used to analyze the number of flowers per plants and the number of fruit per plant in burned and control treatments; Levene's test was used to test for homogeneous variances. At the 3 sites in Lincoln County, a generalized linear model for a generalized randomized block design was used to analyze the effect of prescribed fire on flowering frequency. A general linear model was used to analyze the number of flowers per plant and number of fruits per plant of Kuenzler's cacti; Levene's (1960) test was used to test for homogeneous variances. Both pre-burn and post-burn data were analyzed.

Predicting Fire Effects

Step-wise regression was used to model the effects of fire on Kuenzler's cacti. Each cactus plant was an experimental unit. Sites were not considered a nuisance variable. The dependent variable was cactus epidermis peak temperature during or immediately following a burn measured by the infrared thermometer. Independent variables included fuel load at 3 scales (55 cm, 27, and 15 cm), foliar cover at 3 scales (55 cm, 27, and 15 cm), soil moisture, air temperature, relative humidity, wind speed, slope, aspect, and cactus epidermis temperature before a burn.

Controlled Burning of Greenhouse-Grown Plants

As outlined in our proposal to JFSP, a second component of this research involved burning plants under controlled conditions. This aspect of our work is easily motivated by the following observation: under field conditions, it is possible that although a given Kuenzler's cactus is assigned to a burning treatment (see above), the plant itself may experience no flames and perhaps even little heat if the fuel arrangement around the plant is such that no fine fuel is nearby (Fig. 7). Another common scenario can involve a plant that may be growing very near to a perennial grass that provides fine fuel, but the spacing of fuel associated with the plot is still such that the plant experiences no fire (Fig. 8). Thus, although the *plot* is burned, it is not necessarily true that the *plant* experiences fire. A third scenario involves a cactus located within a matrix of heavy fine fuel that experience flames during burning (Fig. 9). Thus, it is clear that response of field-burned plants may be expected to be variable, depending on the amount and spatial arrangement of the fuel surrounding the cacti.

To address this, we designed a burning protocol that involved manipulating a known fine fuel load and fuel arrangement around plants to be burned as well as the use of a burn barrel (Britton and Wright, 1979). We purchased over 200 Kuenzler's cacti from a local nursery; this purchase was sanctioned by the USFWS (Appendix F). Plants were purchased in April, 2004 and re-potted into clay pots (30-cm diameter, 30-cm depth). Plants were housed in the Texas Tech University Greenhouse and watered approximately 1.5 cm weekly from April, 2004 until April, 2006.

In April, 2006, surviving plants were measured for height and circumference. Plants were assigned to one of 5 experimental treatments; these treatments included two

kinds of prescribed fire. One kind of burning treatment involved simulating a New Mexico landscape with a constructed hillside that measured approximately 6 m by 6 m in surface area; this hillside was positioned so that its southerly aspect had a 17.4° slope, similar to the habitat described in field-studied plants in New Mexico (see Table 2). In the center of this hillside, we dug a hole into which a potted cactus plant could be placed.

We used baled excelsior as fine fuel. This material was comprised of "spur cut" Great Lakes aspen (*Populus tremuloides*) that weighed 13.3 lb/ft^3. Excelsior was oven dried at 60° for 96 hours and then weighed for 2 treatments: a low fuel load treatment used the equivalent of 600 kg/ha, and a high fuel load treatment used the equivalent of 1,200 kg/ha (fuel loads were based on results from field-studied cacti in New Mexico; see Tables 2 and 3). The actual area burned was 12 m^2 (the same plot size that was burned in the field portion of the study). Excelsior was spread out as evenly as possible "by hand" over this plot area and ignited with a hand-held drip torch (Fig. 10).

We instrumented plots with 3 Hobo® temperature probes. Two probes were located at the soil surface 0.75 m to the east and to the west of the potted plant; a third probe was located on the uphill side of the plant, and the temperature sensor was positioned at the height of the apex of the plant. Hobo® temperature data are presented for the maximum temperature experienced during the burning event.

Plants were burned between 11 June 2007 and 25 June 2007. Weather conditions are found in Appendix H. Plants were returned to the greenhouse following burning, and are continuing to be watered every week.

Additional plants were burned in a burn barrel. In this component of the study, plants were exposed to flames in the burn barrel for 5, 10 or 15 seconds. Following burning, plants were returned to the greenhouse.

In September 2007 all greenhouse plants were assessed for fire effects. A plant was defined to be "dead" if it had no green tissue, was "hard" to the touch, and had no evidence of new spination. However, it is important to appreciate that cacti in this genus can have this appearance and may yet be alive, as attested by regrowth up to 6 months after a fire (Rideout-Hanzak et al., submitted). Thus, mortality data collected from these plants should be regarded as "preliminary": plants will be reassessed in the spring of 2008.

Data Analysis

Mortality

Mortality data were analyzed as a completely randomized design using a generalized linear model with a logit link function. A general linear model was used for maximum temperature data. Logistic regression was used to investigate relationships between plant size (height, diameter) and mortality.

RESULTS—FIELD PLANTS IN NEW MEXICO

Plant Characteristics

Study areas differed in mean plant area ($P < 0.0007$) and in variability of area ($P < 0.0007$). Cacti at the WA site were larger in area than cacti at the other sites. Additionally, the variability in area was greater at the WA site than at the other sites; in

fact, the smallest as well as the largest cacti (with respect to area) were found at the WA site (Table 1).

Study areas also differed ($P < 0.0046$) with respect to maximum plant height. However, there were fewer differences among study areas with respect to maximum plant height: i.e., plant height was similar among the 3 sites in Lincoln County, and cacti at the TX-HILL site were shorter than cacti at the NA and WA sites. Additionally, variability in plant height was similar ($P > 0.2805$) among study areas (Table 1).

Study areas differed in average number of stems ($P < 0.0134$) and in variability of number of stems ($P < 0.0044$). Cacti at the NA and WA sites had more stems than cacti at the SA and TX-HILL sites. Cacti at the Lincoln County sites had considerable variability in the number of stems whereas there was very little variability in the number of stems at the TX-HILL site (Table 1).

In general, descriptions of Kuenzler's cactus in Castetter et al. (1976) and Melen (1991) were similar to this study's findings. However, we recorded over 8 stems on a number of cacti, and in this respect these cacti did not fit the published descriptions.

Fuel Load Estimation

Functional equations were selected for 16 species. Sample sizes ranged from $n = 4$ for the less common species, unidentifiable herbaceous litter, and unidentified annuals to $n = 269$ for blue grama. Figure 11 shows the data and the linear function used to predict biomass of sideoats grama. Only 2 species (wolftail (*Lycurus pheoides*) and zinnia (*Zinnia acerosa*)) had an r^2 less than 0.7243. Only equations for litter and zinnia were non-significant ($P > 0.05$). A complete list of functional relationship chosen to predict biomass for each species observed in clipping plots is in May (2006).

Although some relationships chosen were not significant and/or had a low r^2, they were still the best predictors for biomass. Additionally, these species accounted for a very low percentage of the total biomass.

Macro-Habitat

Cacti in this study occurred at elevations ranging from 1,600 m at TX-HILL to 2,100 m at WA (Table 2). The three northern most sites (NA, SA, and WA) were all within about 4 km from each other. Cacti on NA, SA, and WA generally occurred on steep slopes: slopes averaged 16.3°, 16.5°, and 19.4° on NA, SA, and WA respectively. The average slope on TX-HILL was 2.2°. Average aspects of the slopes where cacti occurred ranged from east to south. Fine fuel load (herbaceous biomass) averaged 620, 1,135, 606, and 582 kg ha^{-1} on NA, SA, TX-HILL, and WA respectively.

These findings of cactus locations are very similar to the information in the literature (USBLM 2003). Most cacti in Lincoln County study sites occurred on eastern to southern facing slopes. Although the majority of plants occurred on the upper half of each hill, plants were also found near the bottom of hills, on top of hills, and around eastern to northern bends of hills. Plants were rarely found on north- facing slopes. At the TX-HILL site, all cacti found were on top of the hill on very gentle slopes.

Micro-Habitat

Herbaceous biomass surrounding cacti varied by site. Plants at the SA site were surrounded by an average of 1,135 kg ha^{-1}; NA, TX-HILL, and WA sites had only 582 to 620 kg ha^{-1} of herbaceous biomass surrounding cacti. At each site, however, the amount of herbaceous biomass surrounding cacti was not related to scale of measurement;

herbaceous biomass was similar in circular areas of 30, 56, and 110 cm (diameter) surrounding cacti (Table 3). These results indicate that Kuenzler's cacti are not preferentially located in areas of herbaceous biomass, and therefore do not support the suggestions of DeBruin (1996) that this species may require herbaceous biomass for thermal protection.

Herbaceous foliar cover of vegetation surrounding Kuenzler's cacti also varied by site. Cover was highest at the SA site, intermediate at the NA and WA sites, and lowest at the TX-HILL site. Similar to herbaceous biomass, herbaceous foliar cover at a site was similar across scales of measurement (Table 3). DeBruin (1996) suggested that "healthy" cacti require 24% cover. It is difficult to assess "plant health"; however, the site with the highest herbaceous foliar cover (SA; Table 3) supported *E. kuenzleri* that were intermediate in terms of plant size (Table 1).

Richness of associated flora was similar on all sites within 55, 28, and 15 cm of cacti. Richness increased with distance from a cactus plant (Table 4).

Fire Effects

Flowering

Burning at the TX-HILL site in 2004 did not affect the percentage of plants that flowered in 2004 ($P > 0.6952$) or 2005 ($P > 0.4410$) (Table 5). Fire also did not affect the number of flowers ($P > 0.4818$) or fruits ($P > 0.5618$) per cactus in 2004, the season of treatment, or the number of flowers ($P > 0.9492$) or fruits ($P > 0.7126$) per cactus in 2005, 1 year after treatments (Table 6). For the 3 sites in Lincoln County, data collected in 2004 represent pre-treatment conditions. In 2004, frequency of flowering of cacti assigned to be burned (79.5%, se = 5.5%) was similar ($P > 0.9629$) to frequency of plants

assigned to the control treatment (79.9%, se = 5.5%) (Table 5). In 2005, the growing season following burning, frequency of flowering of burned (77.7%, se = 6.6%) and control (81.8%, se = 5.9%) cacti was not different (P > 0.6334) (Table 5). There was also no difference in the number of flowers (P > 0.8587) or fruits (P > 0.6416) per cactus assigned to different treatments in 2004, 1 year prior to treatments, or the number of flowers (P > 0.5573) or fruits (P > 0.8704) per cactus in 2005, the year treatments were applied (Table 6).

Mortality

This study was designed with 13 cacti each in burn and control treatments at the TX-HILL site, and 96 cacti in each treatment at the Lincoln County sites. However, the actual number of burned and control cacti differ from these numbers for several reasons. Burned cacti totaled 111 (rather than 109) because after a plot was burned and the herbaceous matter removed, additional cacti were discovered in the plot; these additional cacti were monitored as a burned cacti until the end of the study. These additional cacti were not measured for other characteristics and were therefore not included in other aspects of the study. Also, several cacti that had been assigned to a burned treatment were later excluded because after ground-truthing additional cacti were discovered within 2 m of the initially-selected plant. In these cases, the initially selected cacti were used as control cacti.

A total of 243 plants were monitored for mortality in burn and control treatments. Of n = 111 cacti in the burned treatment, there was 8.25% mortality. Of n = 132 cacti in the control treatment, 14.01% died. The effect of burning on cactus mortality was not significant (P > 0.1690). The death of one control plant was a direct result of our study

activity, not a result of a treatment. If this cactus is censored, the results change slightly; of 111 burned cacti, 8.38% died, and of 131 non-burned cacti, 13.54% died; this difference is not significant ($P > 0.2176$). Fire had no significant impact on the mortality of Kuenzler's cacti.

Figures 12 to17 show the pre-burn appearance of several plants; also shown are post-burn photos of these plants documenting recovery following burning that removed spines and caused epidermal injury.

Effects of Fire on Cactus Epidermal Temperature

One objective of this study was to relate cactus response to fire (as recorded by the infrared thermometer) to the fuel load and arrangement around each cactus that was burned. Soil surface temperatures are a function of fuel load (Wright and Bailey 1982). A stepwise regression was used to predict the surface epidermis temperature with fuel load at 3 scales (55 cm, 27, and 15 cm), foliar cover at 3 scales (55 cm, 27, and 15 cm), soil moisture, air temperature, relative humidity, wind speed, slope, aspect, and cactus epidermis temperature before a burn.

The model generated included 3 significant variables and explained about 30% of the variation ($r^2 = 0.3458$) in peak cactus epidermal temperature. The 3 significant variables were fuel load at 55 cm ($P < 0.0376$), foliar cover at 27 cm ($P < 0.0081$), and soil moisture ($P < 0.0319$). When a fourth variable (air temperature: $P > 0.1113$) was included, the 3 previous variables remained significant and the r^2 was 0.3635.

RESULTS—CONTROLLED BURNING IN LUBBOCK

Plant Characteristics

Plants used in the controlled burning experiment were shorter than plants used in the field experiments in New Mexico (Tables 1 and 7). However, there were no differences in height or diameter among treatments for the plants used in the controlled burning experiment (Table 7).

Fire Effects

Maximum Temperature at the Plant Apex

Maximum temperatures recorded at the plant apex were different in each treatment. Although the coolest temperatures were recorded in the excelsior treatments, the 1,200 lbs/acre treatment yielded higher temperatures than the 600 lbs/acre treatment. Similarly, the highest plant apex temperatures were recorded in the burn barrel, and among these treatments, temperatures increased as duration of flame increased (Table 8).

Maximum Temperatures at the Soil Surface

Maximum soil surface temperatures recorded under excelsior fuel (averaged over the 600 and 1,200 lbs/acre treatments) averaged 220.6 F and exceeded ($P < 0.034$) the average maximum soil surface temperature recorded in the burn barrel averaged over the three durations of flame (189.2 F). For the excelsior treatments, average maximum temperature at the surface was higher in the 1,200 lbs/acre than in the 600 lbs/acre treatment. Additionally, maximum soil temperatures in the burn barrel experiments were

higher at the 10-second duration than at the 5- and 15-second durations, and there was no difference in temperatures between the 5- and 15-second duration treatments. These latter results are counter-intuitive and we have no ready explanation.

Mortality

All plants subjected to burning in the burn barrel were apparently dead 3 months post-burning (September, 2007). Figures 18 to 20 illustrate the appearance of plants before, immediately after, and 3 months post burning in the burn barrel for 5, 10, and 15 seconds, respectively. Mortality among control plants (30%) did not differ from mortality in plants burned with 600 kg/ha of excelsior (44%); mortality was higher (74%) for plants burned with 1,200 kg/ha of excelsior (Table 8). Figures 21 and 22 show the appearance two plants, both burned at the low excelsior fuel level. Figure 21 shows a dead plant. Figure 22 shows a plant whose base still shows evidence of damaged tissue; however, new spines and tissue are apparent in the upper portions of the plant.

For plants burned at the high level of excelsior, there was no relationship between mortality and plant height ($P > 0.7234$) or plant diameter ($P > 0.2224$). However, for plants burned at the low level of excelsior, there was a negative relationship between mortality and plant height ($P < 0.0173$) and a negative relationship between mortality and plant diameter ($P < 0.0218$): that is, smaller plants had a higher probability of mortality at the low level of excelsior.

DISCUSSION

This study was conducted in two complementary phases. Field work using plants in their native habitat was conducted at 4 study sites in New Mexico. In the Fort Stanton Management area (Lincoln Co., NM), 3 hillsides separated by at least 1.6 km were studied, the fourth study site was 130 km to the south in Eddy County, NM. This phase of the work involved a detailed characterization of the macro- and micro-habitat of Kuenzler's cactus, with special emphasis on describing the amount and spatial arrangement of fine fuel that surrounds individual plants. Additionally, this phase studied the response of plants to prescribed fire. A second phase of this work utilized nursery-purchased plants that were grown under greenhouse conditions for 2 years before subjecting them to burning under carefully controlled conditions using either a burn barrel or hand-applied and arranged excelsior as a fuel source for burning. Both components of this study should be considered when evaluating the response of this plant to fire.

When Kuenzler's cactus was listed as an endangered species in 1979, total population estimates were as low as 250 cacti. Surveys in the 1990s increased the number of known cacti to around 2,500 plants. In this study, 2,449 cacti were located in only 21 hillsides. The number of plants located on the WA site and one other non-study site outnumbered a previous survey of the same locations 10 to 1. In 4 locations in the Ft. Stanton Area of Environmental Critical Concern identified by the USBLM, 176 cacti were known to occur. When we surveyed these locations, we found 556 plants, and also discovered a previously unknown area that contained Kuenzler's cacti. Kuenzler's cactus can be hard to detect. Many other cacti at these study sites were unrecorded on NA, SA,

WA, and TX-HILL simply because cacti were found after GPS locations had been recorded. There are many south- to east- facing hillsides between 1,600 and 2,100 m in elevation that occur between our study sites in Eddy and Lincoln Counties. Although many hillsides may not support populations of Kuenzler's cactus, current population estimates may not be accurate because the number of possible hillsides surveyed may be quite low. Furthermore, Melen (1991) stated that Kuenzler's cacti were found as far south as the Santa Clara Valley in Chihuahua, Mexico. Therefore, Kuenzler's hedgehog cactus numbers seem to be much larger and potential habitat may be broader than once thought. In fact, our results have been cited by the U.S. Fish and Wildlife Service's "Five-Year Review" of Kuenzler's cactus written in 2005 (Appendix J).

Our findings concerning the macro- and micro-habitat characteristics of Kuenzler's cactus are consistent with Chauvin et al. (2001) and US BLM (2003). This species grows on the southern to eastern slopes of south central New Mexico between 1,600 and 2,100 m in elevation. Relative to suggestions of habitat requirements involving biomass and cover (DeBruin 1996), our micro-habitat data suggest that this species does not grow in areas with more or less biomass or cover than what is available on the average in my four study sites.

Under the burning conditions of the field portion of this study (Appendices H), fire had no impact on the frequency of flowering or the number of flowers or fruits per plant of Kuenzler's cactus 1 or 2 growing seasons post burn. In the literature, fire has been shown to increase flowering, recruitment, seed production, and seed germination in some species (Boyd and Serafini 1992, Hartnett and Richardson 1989, Kaye et al. 2001, Lesica 1999, Menges 1995, Norden and Kirkman 2004). Norden and Kirkman (2004)

also showed that the increased light availability resulting from removing herbaceous material actually stimulates flowering and seed production, which can be achieved without burning. Keeley and Keeley (1987) found no benefit to germination from heated seeds in xerophytic shrubs and herbaceous species. However, D'Antonio et al. (1993) and Boyd and Serafini (1992) found that heating stimulated seeds inside fruits and increased seedling emergence. However, Kuenzler's cacti showed no flowering response to prescribed fire.

Additionally, under the burning conditions of the field portion of this study (Appendix H), prescribed fire had no impact on the mortality of Kuenzler's cacti 1 or 2 growing seasons post burn. Thomas and Goodson (1991) noted mortality of 2 *Echinocereus* species with fuel loads of 800 g m^{-2} (8,000 kg ha^{-1}). The largest fuel load estimate in this study was 3,927 kg ha^{-1} at the SA site (in the 30-cm diameter scale). SA also had the highest average fuel load of 1,155 kg ha^{-1}, a fraction of the 8,000 kg ha^{-1} reported by Thomas and Goodson (1991) as harmful to *Echinocereus*. It is highly unlikely for fine fuel loads in the pinyon-juniper habitat of Kuenzler's cactus to reach 8,000 kg ha^{-1}. However, encroaching juniper could increase fuel loads and the risk of a catastrophic fire to Kuenzler's cactus. The encroachment of these woody species is usually the target of prescribed fires which has shown to be highly effective (Wright and Bailey 1982).

Results for phase 2 of this study (utilizing known amounts of excelsior for fine fuel, or burning in a burn barrel for specified durations of time) provide additional information on the response of this species to fire. In particular, when Kuenzler's cacti

were exposed to the flames of a burn barrel, even for as little as 5 seconds, we recorded 100% mortality 3 months post burning.

When plants were burned with the equivalent of 600 lbs/acre of fine fuel (in the form of excelsior), an amount of fuel similar to average fuel loads we recorded in the native habitat of Kuenzler's cactus, mortality was not different from that observed in non-burned plants. However, for these plants, smaller plants had a higher probability of mortality than larger plants. When we burned plants with the equivalent of 1,200 lbs/acre, an amount that represents a high, but still reasonable fuel load for the habitat of this species, we recorded a significant increase in plant mortality 3 months post burning. For these plants, there was no relationship between plant size and mortality. *It will be imperative that we document long-term mortality* (*that is, mortality 1 and 2 years post burning*). Until then, however, we conclude that when these plants experience fire under conditions of high fuel load, they experience more mortality than non-burned plants; also, smaller plants may be at risk when burned under "normal" fuel loads.

Fire is a naturally-recurring event in pinyon-juniper habitats. This ecosystem and the plants in it, including Kuenzler's cactus, are adapted to recurring fire. Prescribed fire is a viable range management technique that will not impact Kuenzler's cactus when burning is conducted under fuel load conditions that represent the equivalent of 600 lbs/acre. The lack of a fire effect on Kuenzler's cactus in these conditions does not mean a wild fire or a prescribed fire preceded or followed by extreme weather patterns would not affect the species. In fact, our results show that burning with higher fuel loads will cause increased mortality. Sivinski (1999) reported a severe and negative impact to Kuenzler's cactus resulting from a wildfire. Rideout-Hanzak et al. (unpublished) found

90% mortality in *Echinocereus viridiflorus* var. *viridiflorous* after a wildfire on Buffalo Lakes National Wildlife Refuge (BLNWR). However, the fire on BLNWR occurred after 2 years of above-average precipitation in a pasture that was not grazed (suggesting considerable accumulation of fine fuel) and was followed by drought conditions. The area burned and drought conditions persisted in the months following the fire. These drought conditions may explain the 20% mortality in *E. viridiflorus* var. *viridiflorous* on the non-burned areas. Therefore, the timing of a burn may be important, as well as growing conditions both prior to and following a fire. There is no way of predicting the weather 6 months after a target burn date, but ample precipitation in the months preceding a target burn date may reduce the stress on a plant.

Even though fire had no effect on mortality or flowering of Kuenzler's cactus, peak epidermal surface temperatures of cacti during a prescribed fire were related to fuel load in the entire study plot, the percent foliar cover within 27 cm of a cactus, soil moisture, and air temperature. These variables are measurements of fuel load and fuel arrangement surrounding cacti. Clearly, prescribed fire affected the surface temperature of these cacti, and these effects were related to the amount and arrangement of fuel. These variables should be considered in future research to determine the threshold at which fire can be detrimental to Kuenzler's hedgehog cactus. Plant size also is important in the response of this species to burning under average fuel conditions. These factors should be considered when executing a prescribed fire in an area containing Kuenzler's cactus.

TIME LINE OF PROJECT

This project was funded in August, 2002. A graduate student was hired in the fall of 2002. Field work began in the spring of 2003. Field surveys in Eddy and Lincoln counties were conducted throughout 2003 and 2004. In November 2002, the USFWS issues its Draft Biological Assessment. In February 2003 we provided documentation requested permission to use a larger number of plants. Based on 2003 field work, we were given permission in November, 2003 to burn 13 plants in Eddy Co. and 96 plants in Lincoln Co. We were prepared to burn plants in the spring of 2004, with an experiment designed to compare seasons of burn in Lincoln Co. However, Lincoln Co. issued a burn ban, and we were unable to burn plants in the spring or summer of 2004. However, 13 plants were burned in Eddy Co. in 2004. In the spring of 2004, we purchased plants from a nursery, re-potted them, and housed them in the TTU greenhouse.

Given our experience with a burn ban in 2004, we decided that we would burn all plants as soon as possible in 2005 in Lincoln Co. Throughout 2005, we collected post-burning data from plants in Eddy and Lincoln Cos. Also in 2005, we began experimenting with the burn barrel. Considerable efforts were expended in modifying the barrel to burn cacti. This work continued through the summer of 2005. In autumn, 2005, the graduate student on this project made some personal decisions that required him to complete his thesis in 2006. At this stage, we suspended work on the burn barrel and focused on completing the field portion of this project.

It was the understanding at Texas Tech University, both on the part of the PI as well as the Offices of Research Services and of Accounts Payable, that this project had an end-date of 2008—this was the date listed in the Assistance Agreement that was signed

between the Bureau of Land Management and Texas Tech University (Appendix K). However, JFSP notified us in the summer of 2006 that the end-date of this project was September, 2006. We negotiated a one-year no cost extension to complete this work. Phase 2 of this work, which involved burning greenhouse-grown plants under controlled conditions, was conducted in June, 2007to coincide approximately with the seasons of burn in the field portion of this study in New Mexico.

DELIVERABLES

During the funding period for this project, the principal investigator has participated in each of the Principal Investigator's annual meetings hosted by the Joint Fire Science Program. We have presented the results of this project that the annual Principal Investigator's meeting in 2005. Additionally, we have presented results from this work at the Third International Wildfire Congress held in 2006 and at the Texas Section of the Society for Ecological Restoration in 2006. One Master's thesis has been completed. Three scientific publications are in preparation (see Appendix L).

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and provided much needed data entry. Dr. Ernest Fish and his staff in the Geospatial Technologies Lab (Department of Natural Resources Management, Texas Tech University) provided technical assistance throughout this project. Dr. Sandra Rideout-Hanzak has provided crucial input and assistance for 2 years on this project—without her advice and help, it would not have been possible to burn plants in Lubbock.

Table 1. Plant characteristics of Kuenzler's cacti measured in 2004 at the TX-HILL study site in Eddy Co. and the NA, SA, and WA sites in Lincoln Co., NM.

Plant Characteristic	Site	N	Mean	Variance	SE	Minimum	Maximum
Area[1/] (cm^2)	NA	62	45.16 b[2/]	906.61b[3/]	3.82	8.49	166.19
	SA	32	38.94 b	469.01c	3.83	7.55	82.88
	TX-HILL	24	33.71 b	728.37bc	5.51	2.83	117.31
	WA	100	61.39 a	2125.00a	4.61	2.42	252.25
Height (cm)	NA	48	7.45 a	11.48a	0.49	1.5	14.00
	SA	25	7.26 ab	9.25a	0.61	1.0	12.00
	TX-HILL	26	5.94 b	7.47a	0.54	0	11.00
	WA	61	8.56 a	9.56a	0.40	1.0	12.00
No. of stems	NA	54	2.22 a	3.27ab	0.25	1.0	11.00
	SA	28	1.64 b	2.16b	0.28	1.0	7.00
	TX-HILL	24	1.21 b	0.26c	0.10	1.0	3.00
	WA	77	2.44 a	4.30a	0.25	1.0	15.00

[1/] Area of cacti in cm^2 was measured from digital photographs using the procedures described in the Materials and Methods: Data Collection: Habitat Characteristics.

[2/] Means among sites for a given characteristic followed by the same letter are not significantly different ($P > 0.05$, protected LSD).

[3/] Variances among sites for a given characteristic followed by the same letter are not significantly different ($P > 0.05$, pairwise F_{max} test).

Table 2. Macro-habitat characteristics containing Kuenzler's cacti at the TX-HILL study site in Eddy Co. and the NA, SA, and WA study sites in Lincoln Co., NM.

Characteristic	Site	Mean	SE	Minimum	Maximum
Elevation (m)	NA	.	.	2000	2050
	SA	.	.	2040	2080
	TX-HILL	.	.	1600	1620
	WA	.	.	2040	2100
Slope (°)	NA	16.3	1.0	3	41
	SA	16.5	1.1	6	29
	TX-HILL	2.7	0.3	0	7
	WA	19.4	0.8	0	35
Aspect (°)	NA	86.9	3.8	40	290
	SA	140.9	5.4	80	200
	TX-HILL	88.5	7.5	Level	180
	WA	95.7	1.7	Level	120
Biomass[1/]	NA	620	33	36	1363
(kg ha^{-1})	SA	1155	84	315	2188
	TX-HILL	664	67	51	1321
	WA	583	32	36	1460

[1/] Biomass estimations were made the year sites were burned: site TX-HILL was burned in 2004, sites NA, SA, and WA were burned in 2005.

Table 3. Micro-habitat characteristics surrounding Kuenzler's cacti at 3 scales in 2004 at the TX-HILL study site in Eddy Co. and in 2005 at the NA, SA, and WA study sites in Lincoln Co., NM.

Variable	Plot Size[1/]	Mean	SE	Minimum	Maximum
NA Site:					
Biomass ($kg\ ha^{-1}$)	Large	620a[2]	32.60	36	1363
	Medium	629a	45.75	0	1935
	Small	680a	54.93	0	1999
Herbaceous foliar cover (%)	Large	15.93a	0.78	0.19	30.56
	Medium	15.06a	0.95	0.41	40.80
	Small	14.81a	1.07	0	40.63
SA site:					
Biomass ($kg\ ha^{-1}$)	Large	1155a	84.41	315	2188
	Medium	1305a	143.37	53	3448
	Small	1361a	180.83	0	3927
Herbaceous foliar cover (%)	Large	23.47a	1.70	7.64	41.96
	Medium	24.55a	2.46	1.51	54.23
	Small	24.35a	2.82	0	53.57
TX-HILL site:					
Biomass ($kg\ ha^{-1}$)	Large	664a	66.76	51	1321
	Medium	641a	107.25	0	2294
	Small	539a	112.04	0	1785
Herbaceous foliar cover (%)	Large	9.98a	0.89	0.68	17.82
	Medium	8.54ab	1.31	0	23.08
	Small	6.75b	1.39	0	26.42

WA site:

Biomass (kg ha^{-1})	Large	583a	31.93	36	1460
	Medium	572a	41.31	0	2291
	Small	540a	44.84	0	2429
Herbaceous foliar cover (%)	Large	11.32a	0.54	0.95	24.36
	Medium	11.06a	0.68	0	38.72
	Small	9.96b	0.73	0	36.59

[1] Plot sizes are large (110 cm in diameter); medium (56 cm in diameter), and small (30 cm in diameter).

[2]Means among sites for a given characteristic followed by the same letter are not significantly different (P > 0.05, protected LSD).

Table 4. Species richness surrounding Kuenzler's cacti at 3 scales in 2004 at the TX-HILL study site in Eddy Co. and in 2005 at the NA, SA, and WA study sites in Lincoln Co., NM.

Site	Plot Size [1/]	Mean	SE	Minimum	Maximum
NA	Large	3.37	0.15	1	6
	Medium	2.66	0.13	1	5
	Small	1.85	0.10	0	4
SA	Large	3.72	0.24	1	6
	Medium	2.72	0.21	1	5
	Small	1.69	0.18	0	5
TX-HILL	Large	4.08	0.25	1	7
	Medium	2.40	0.29	0	6
	Small	1.56	0.21	0	3
WA	Large	3.70	0.13	1	7
	Medium	2.70	0.12	0	6
	Small	1.75	0.09	0	5

[1/] Plot sizes are large (110 cm in diameter); medium (56 cm in diameter), and small (30 cm in diameter).

Table 5. Effect of burning on frequency of flowering of Kuenzler's cacti at the TX-HILL study site in Eddy Co. and the NA, SA, and WA study sites in Lincoln Co., NM. Burns were conducted in April and June 2004 at the TX-HILL site and in March 2005 at the 3 sites near Ft. Stanton. Plant response data were collected monthly in 2004 and 2005.

		Burn		Control		
Year	Site	Percent of cacti that flowered	SE	Percent of cacti that flowered	SE	P-value
2004	TX-HILL	38.5	13.5	46.2	13.8	0.6952
	FS[1/]	79.5	5.5	79.9	5.5	0.9629
2005	TX-HILL	61.5	13.5	46.2	13.8	0.4410
	FS	77.7	6.6	81.8	5.9	0.6334

[1/] Sites = FS represents the 3 sites in the Ft. Stanton Area of Environmental Critical, NM Concern: NA (north of airport), SA (south of airport), and WA (west of airport sites combined.

Table 6. Effect of burning on the average number of flowers and fruits per Kuenzler's cacti at the TX-HILL study site in Eddy Co. and the NA, SA, and WA study sites in Lincoln Co, NM. Burns were conducted in April and June 2004 at the TX-HILL site and in March 2005 at the 3 sites near Ft. Stanton. Plant response data were collected monthly in 2004 and 2005.

			Burn		Control		
Year	Site		Average no. per plant	SE	Average no. per plant	SE	P-value
2004	TX[1/]	Flowers	0.5385	0.2433	0.8462	0.3553	0.4818
		Fruits	0.4615	0.2433	0.6923	0.3077	0.5618
	FS[1/]	Flowers	2.0540	0.3343	1.9611	0.3454	0.8587
		Fruits	0.8889	0.1930	1.0333	0.1831	0.6416
2005	TX	Flowers	0.6923	0.1748	0.7143	0.2965	0.9492
		Fruits	0.5385	0.1831	0.4286	0.2362	0.7126
	FS	Flowers	2.3863	0.5709	2.6655	0.5667	0.5573
		Fruits	1.4184	0.4207	1.4724	0.4219	0.8704

[1/] Site = TX represents the TX-HILL site ; FS represents the 3 sites in the Ft. Stanton Area of Environmental Critical, NM Concern: NA (north of airport), SA (south of airport), and WA (west of airport) sites combined.

Table 7. Mean (se) height (mm), diameter (mm), and number of plants of Kuenzler's cacti used in the controlled burning experiments in Lubbock, TX-HILL.

		Excelsior		Burn Barrel		
		Fuel Load (lbs/acre)		Duration of Flame (seconds)		
	Control	600	1,200	5	10	15
	(n = 39)	(n = 59)	(n = 58)	(n=9)	(n=10)	(n=10)
Height (mm)						
Mean	48.4 a	47.0 a	46.5 a	46.6 a	51.9 a	47.2 a
Std. error	1.19	0.91	0.78	1.51	1.84	2.17
Diameter (mm)						
Mean	5.51	5.38	5.40	5.40	5.45	5.54
Std. error	0.07	0.05	0.06	0.11	0.10	0.22

1/ Treatment means of a characteristic followed by the same lower case are not significantly different (P > 0.05, protected LSD test).

Table 8. Mortality (%) (standard error) of Kuenzler's cacti burned in controlled burning experiments in Lubbock, TX-HILL., in June, 2007; mortality assessed in September, 2007. Plants were recorded as "dead" if they lacked green tissue, were hard to the touch and desiccated, and showed no evidence of new spination. Mortality data will be re-collected in spring, 2008, to confirm results. Also shown are maximum temperature (° C) reached at the plant apex and at the ground surface during the burn event.

		Excelsior Fuel Load (lbs/acre)		Burn Barrel Duration of Flame (seconds)		
	Control	600	1,200	5	10	15
Mortality (%)	30.8 a [1/]	44.1 a	74.1 b	100.0 c	100.0 c	100.0 c
	(n=39)	(n=59)	(n=58)	(n=9)	(n=10)	(n=10)
Standard error	7.39	6.46	5.75	--	--	--
Maximum temperature at plant apex (°C)	--	106.7 a	137.2 b	235.2 c	369.3 d	498.6 e
		(n=54)	(n=56)	(n=10)	(n=10)	(n=10)
Standard error	--	10.4	11.7	18.3	23.5	15.2
Maximum temperature at ground surface (°C)		197.0	244.3	152.2	223.4	192.0
		(n=55)	(n=58)	(n=10)	(n=10)	(n=10)
Standard error		13.0	12.2	11.8	26.9	16.9

[1/] Percents within a row followed by the same letter are not significantly different (P > 0.05, protected LSD).

Figure 1. A flowering Kuenzler's cactus in Lincoln County on 13 May 2005.

Figure 2. A Kuenzler's cactus with multiple stems.

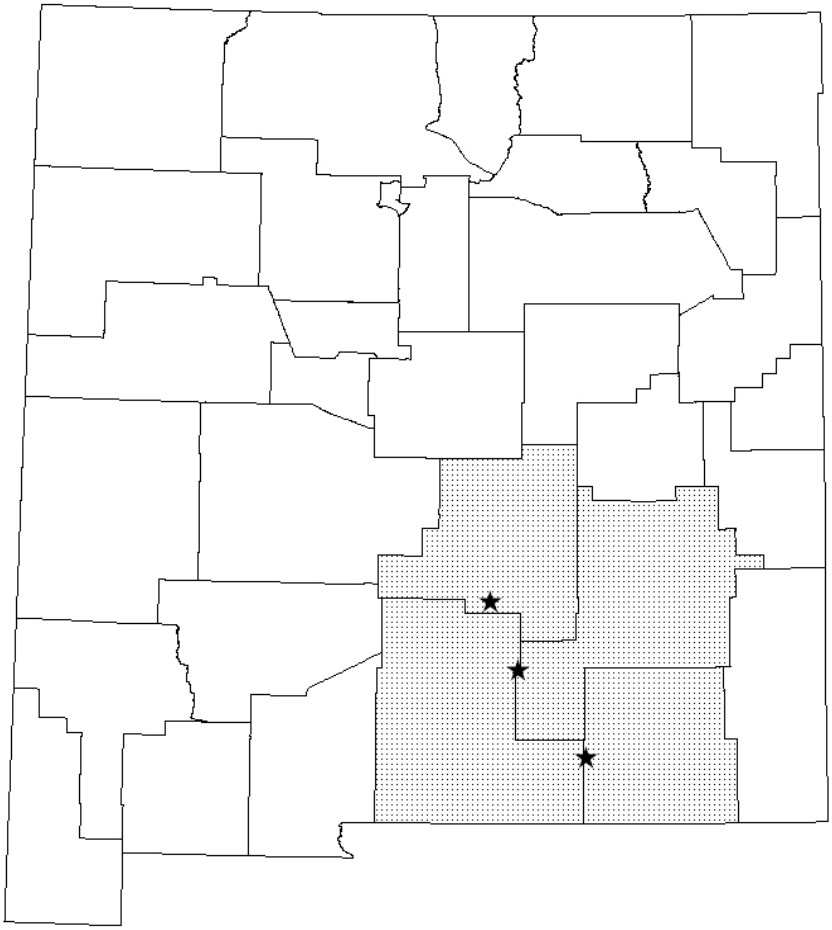

Figure 3. Map of the 4 counties (Lincoln, Otero, Chaves, and Eddy counties) in New Mexico known to contain Kuenzler's cacti. From north to south stars mark: Ft. Stanton research area; Elk, N.M. (the first documented population); Texas Hill research area.

Figure 4. General landscape view of the study area in Lincoln County, New Mexico.

Figure 5. General landscape view of the study area in Eddy County, New Mexico.

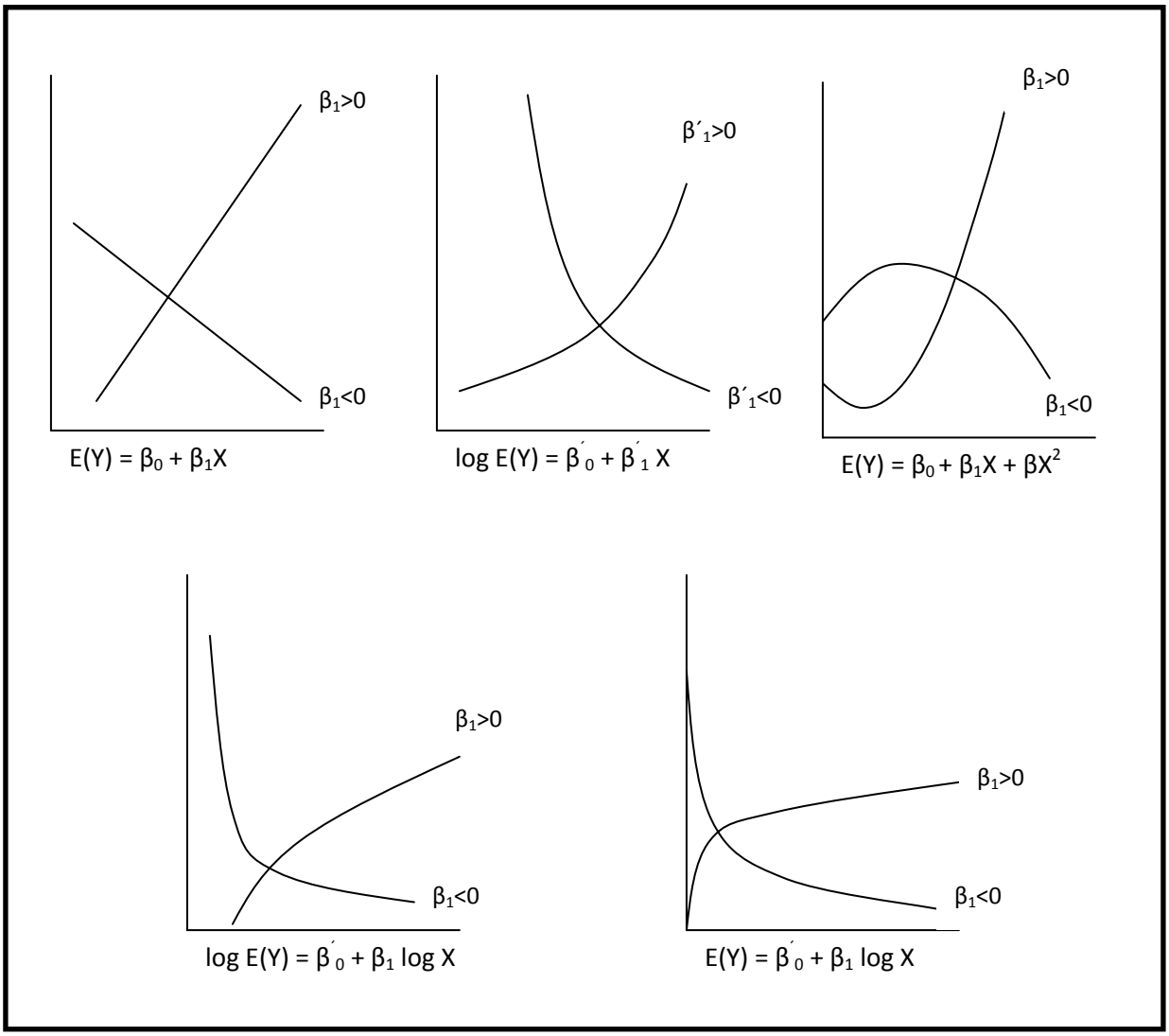

Figure 6. Functional relationships considered to estimate herbaceous biomass (Steel and Torrie 1980).

Figure 7. This burned plot is at the TX-HILL study site. The 10-m^2 plot is centered over the Kuenzler's cactus plant, but here is very little fine fuel nearby.

Figure 8. A Kuenzler's cactus plant is located in the center of this photo at the base of a perennial grass plant. Sparse fuel this plot is such that, even though the cactus plant is nestled at the base of a grass plant, it did not burn.

Figure 9. A Kuenzler's cactus plant is located at the base of the shrub located just to the right of the center of the photograph. This is an example of a cactus plant that experienced flames during plot burning.

Figure 10. This constructed hillside measures approximately 6 m x 6 m, with a southern slope of 17°, similar to landscapes in New Mexico that support Kuenzler's cactus.

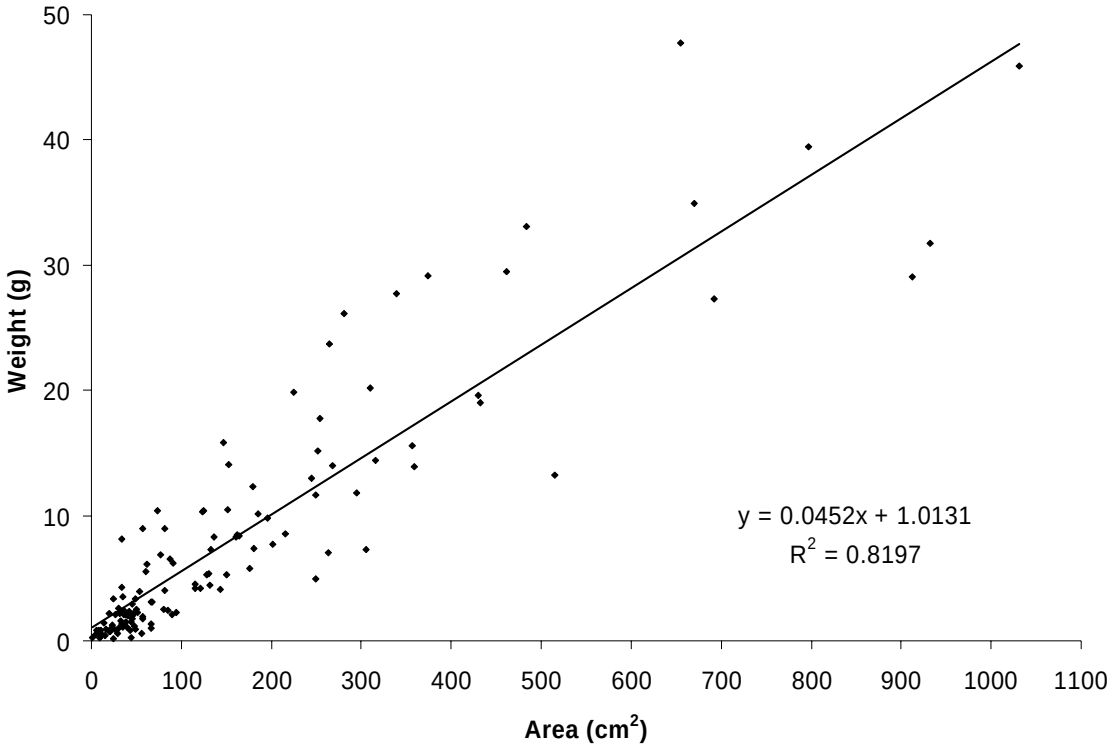

Figure 11. Relationship used to predict biomass of sideoats grama from foliar cover on 4 study sites in the mountains of south central New Mexico.

Figure 12. Pre-burn photograph (top) and a post-burn photo (bottom) of Plant No. 84 taken approximately 3 months after burning. Note that the fire removed spines from the plant, and it is pale-green

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Figure 13. Post-burn photo of Plant 84 taken approximately 5 months after burning. Note that the lower portion of the plant is pale green, and few spines have been replaced. The upper portion of the plant is dark green with new spination and a flower.

Figure 14. Pre-burn appearance of Plant No. 573.

Figure 15. Post-burn appearance of Plant No. 573 approximately 3 weeks post burning. Note that fire removed most of the spines from this plant.

Figure 16. Post-burn appearance of Plant No. 573 approximately 15 months post-burning. Note that a vegetative “pup” has been produced on the lower left portion of the plant.

Figure 17. Post-burning appearance of Plant No. 573 approximately 27 months post-burning. Note that the vegetative pup shown in Figure 12 is now located on the left side of the plant in this photo. Also, this plant produced a flower.

a) Prior to burning

b) Immediately after burning

c) 3 months post burning

Figure 18. Plant No.85, burned for 5 seconds in the burn barrel, before and after burning.

a) Prior to burning

b) Immediately after burning

c) 3 months post burning.

Figure 19. Plant No.151, burned for 10 seconds in the burn barrel, before and after burning.

a) Prior to burning

b) Immediately after burning

c) 3 months post burning

Figure 20. Plant No.32, burned for 15 seconds in the burn barrel, before and after burning.

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Figure 21. Plant No. 19 was burned at the low excelsior fuel level, and it is apparently dead 3 months post burning.

Figure 22. Plant No. 72 was burned at the low excelsior fuel level, and it is alive 3 months post burning.

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APPENDICES

Appendix A: Draft Biological Assessment USFWS: November 24, 2002

United States Department of the Interior
FISH AND WILDLIFE SERVICE
New Mexico Ecological Services Field Office
2105 Osuna NE
Albuquerque, New Mexico 87113
Phone: (505) 346-2525 Fax: (505) 346-2542

November 24, 2002

Cons. #2-22-03-I-0078

Memorandum

To: Field Manager, Bureau of Land Management
Carlsbad Field Office, Carlsbad, New Mexico

From: Field Supervisor, U.S. Fish and Wildlife Service, New Mexico Ecological Services Field Office, Albuquerque, New Mexico

DRAFT

Subject: Biological Assessment for effects of prescribed fire on Kuenzler's hedgehog cactus

This memorandum is in response to your biological evaluation (BE), received November 4, 2002, for the effects of a prescribed fire research project on Kuenzler's hedgehog cactus (*Echinocereus fendleri* var. *Kuenzleri*), on Bureau of Land Management (BLM) lands located along the northeastern escarpment of the Guadalupe Mountains in southeastern New Mexico. This memorandum is in accordance with the Endangered Species Act (87 Stat. 884, as amended; 16 U.S.C. 1531 *et seq.*).

As stated in the BE, the BLM is proposing a research project to determine the effects of fire on individual cacti and population dynamics. We support research which will assist the Carlsbad Field Office (CFO) in effectively managing natural resources, and agree that prescribed fire can be a beneficial tool toward restoring ecosystems. We provided informal comments on an earlier biological assessment and evaluation (BAE) by telephone on August 1, 2002. Although many of our concerns and comments were incorporated into the November 1, 2002, BA, we have several concerns and requests for clarification remain.

1. According to the earlier BAE, BLM had identified 80 cacti that could be burned during the proposed study. Twenty each would be burned in spring, summer, and fall prescribed burns, and twenty would be burned in burn barrels (a barrel placed over a cactus which allows for a specific temperature burn). In our August 1, 2002, telephone conversation we expressed our concern that this number of cacti could be a significant loss to the known Guadalupe Mountain Kuenzler's hedgehog cactus population,

DRAFT

which is 259 (Chauvin 2001). The number of cacti included in the burn study increased in the November 1, 2002, BE which identifies up to 119 Kuenzler's hedgehog cacti to be included in the research project, of which 95 may be burned. Thirty each would be burned in the Spring and Fall and 35 in burn barrels. This represents 37 percent of the known Guadalupe Population, and 6 percent of the known global population (Chauvin 2001). We remain concerned by the number of cacti which may be killed by the proposed project.

1) How has the number of cacti to be burned in the study been determined?

2. Please include in the BA specific justification why a surrogate cannot be used in the burn barrels. In our August 1, 2002, telephone comments we recommended a surrogate cactus, such as the rainbow cactus (*Echinocereus chloranthus*), be used in the burn barrels.

3. The proposed project is currently planned for three years. The age to sexual maturity for the Kuenzler's hedgehog cactus is 4-5 years. We recommend the study be extended to at least five years in order to evaluate the effects of fire on cactus reproduction.

4. The proposed study will investigate Kuenzler's hedgehog cactus burn response in the absence of cattle grazing, through use of electric fences to exclude cattle from the burn plots. In future land management situations, it may not be possible to exclude cattle from areas which have been burned.

   1) In the future, if cattle are allowed on post-prescription burned lands, then the proposed research project should include an evaluation of cattle impact to Kuenzler's hedgehog cacti after prescription burns.

5. Include the (DeBruin, 1996), and (Chauvin et al 2000) (Chauvin 2001) references in the Literature Cited section.

We look forward to resolving these remaining questions and completing the consultation in an expeditious manner. In future communications regarding this memorandum or the proposed project, please refer to Consultation #2-22-03-I-0078. If you have any questions, or need for clarification concerning this memorandum, please contact Bill Ostheimer of my staff at (505) 346-2525, ext. 137.

DRAFT

Joy E. Nicholopoulos

Field Supervisor

Literature Cited:
Chauvin, Yvonne., A. Kennedy, K. Wild. 2001 Survey for Kuenzler's Hedgehog Cactus (*Echinocereus fendleri var.kuenzleri*). Prepared for Bureau of Land Management, Carlsbad Field Office, Carlsbad, New Mexico

Appendix B: Texas Tech University's February 11, 2003 Response to USFWS, November 24, 2003

TEXAS TECH
UNIVERSITY
Range, Wildlife, and Fisheries Management
Phone: 742-2841
Fax: 742-2280
MS 2125

February 11, 2003

Dr. Joy E. Nicholopoulos
U.S. Department of Interior
New Mexico Ecological Services Field Office
Fish and Wildlife Service
2105 Osuna NE
Albuquerque, NM 87113

Mr. Ty Bryson
Bureau of Land Management
620 East Greene Street
Carlsbad, New Mexico 88220

Dear Dr. Nicholopoulos and Mr. Bryson:

Please find accompanying this letter a short paper that I have put together dealing with sample size issues and other concerns of the Kuenzler cactus project as expressed by the Ecological Services Office in Albuquerque in a draft dated 24 November 2002 (Cons. #2-22-03-I-0078). We appreciate the comments and concerns of the USFWS. Below is an itemized response that follows the organization of the Ecological Services Office draft.

1. We would like to conduct the field study and the burn barrel study in two separate locations. In this way, the relative proportion of plants that are possibly affected will be reduced in each area, without compromising the research.

   Clearly, the experimental set-up must address the issue of just how large a burning effect is to be detected. As the accompanying paper illustrates in some detail, if it is important to detect a relatively small treatment effect (should one exist), then a relatively large sample size will be required. If the treatment effect to be detected (should it exist) is relatively large, then a smaller number of cacti will be needed.

2. We strongly feel that it will be unacceptable from a scientific viewpoint to use a surrogate cactus for the burn barrel study. In our judgment, this is simply not "good science": it is our strong opinion that if we want to study the effects of fire on Kuenzler's cactus, then we simply have to use Kuenzler's cactus. We are convinced

that the scientific community will not accept results from a surrogate cactus as being applicable to Kuenzler's cactus.

There are numerous examples that can be drawn from the fire ecology literature to support our contention. For example, the intermountain basin region supports a number of cool season bunchgrasses (e.g., bluebunch wheatgrass, bottlebrush squirreltail, Idaho fescue, and numerous needlegrasses. All have similar growth forms and seasons of growth, and all are native except crested wheatgrass. Despite many similarities in general growth form and life history traits, bluebunch wheatgrass, squirreltail and crested wheatgrass are less susceptible to fire injury than Idaho fescue and many of the needlegrasses because they are composed primarily of coarse stems with a minimum of leafy material. Among bluebunch wheatgrass, needle-and-thread, and Idaho fescue, for example, there are important differences in response: bluebunch wheatgrass returns to pre-burn production in one to three years after a fire, needle-and-thread in three to eight years, and Idaho fescue in two to twelve years. All of these species are cool season bunchgrasses that are often found together ecologically, but this is no reason to conclude that the effects of fire on them are similar (see H.A. Wright and A.W. Bailey. 1982. Fire Ecology, Wiley-InterScience, 501 pp.). If one were to conduct fire research on one of these species, and then, by appealing to the fact that the other species were similar in growth form and important life history traits, they should also respond similarly, the conclusions would simply be inaccurate.

It is easy to imagine a critic of our results saying "So, you didn't really use Kuenzler's cactus in the burn barrel study. Show me the data that justify applying the results from a species that is not Kuenzler's cactus to Kuenzler's cactus."

We do not want our research to be vulnerable to this kind of criticism: the only best way to document the effects of fire on Kuenzler's cactus is to study Kuenzler's cactus.

3. We would be pleased to continue this study for at least five years, and will make every effort to acquire funding to do so.

4. We agree that the effects of grazing should be included in the proposed research, and are willing to include this factor.

Please let us know if we can provide any additional information in this matter. We are anxious to conduct this research by the highest standards of scientific credibility possible, and appreciate your input in its planning process.

Sincerely,

David B. Wester
Professor
Range, Wildlife, and Fisheries Mgt.
david.wester@ttu.edu

EFFECTS OF FIRE ON KUENZLER'S HEDGEHOG CACTUS (*ECHINOCEREUS FENDLERI* VAR. *KUENZLERI*), AN ENDANGERED SPECIES IN THE NORTHERN CHIHUHAUAN DESERT

SAMPLE SIZE CONSIDERATIONS

David B. Wester
Department of Range, Wildlife, and Fisheries Management
Texas Tech University
Lubbock, Texas 79409

February 6, 2003

EFFECTS OF FIRE ON KUENZLER'S HEDGEHOG CACTUS (*ECHINOCEREUS FENDLERI* VAR. *KUENZLERI*), AN ENDANGERED SPECIES IN THE NORTHERN CHIHUHAUAN DESERT

SAMPLE SIZE CONSIDERATIONS

1. Sample size considerations relate to availability of experimental units (i.e., number of local populations, and number of plants in each population, that are available to be burned) and statistical concerns.

   In this research, the primary measure of fire effects on cactus is plant death. Thus, the outcome is dichotomous. Although the research includes two burning treatments (spring or summer burning) and a control (unburned), *a priori* interest focuses on a comparison between (1) the control and the spring burn, and a comparison between (2) the control and the summer burn.

2. Terms used are defined below:

   • *Control*: a plot that will be studied but not burned.

   • *Treatment:* a plot that will be burned; treatments are either spring burning or summer burning.

   • *Plot:* an experimental unit for the field burning experiment; each plot will contain n_{ij} plants (see below).

   • *n:* number of cactus plants per experiment; this is the sum of all cactus plants in all plots of all treatments.

   • n_i*:* number of cactus plants in the ith treatment.

   • n_{ij}*:* number of cactus in the ith treatment and the jth plot.

   • p_c*:* probability of cactus death in the control; p_c is also the proportion of cactus plants in the control treatment which die.

   • p_t*:* probability of cactus death in a burning treatment; p_t is also the proportion of cactus plants in a burning treatment which die.

   • α*:* the probability of a Type I error in a statistical test of hypothesis. This is the probability of rejecting the null hypothesis of equality of treatments when in fact this hypothesis is true.

• β*:* the probability of a Type II error in a statistical test of hypothesis. This is the probability of failing to reject the null hypothesis of equality of treatments when in fact it is false.

• *Power:* the probability of rejecting the null hypothesis of equality of treatments when it is false. This is the probability of detecting a difference between treatments when in fact there is a difference.

3. The following assumptions are made in this analysis:

   a) The probability that a cactus dies in a control plot is either $p_c = 0.05$ or $p_c = 0.20$. The lower value may be applicable for relatively stable populations with low natural mortality. The higher value may be applicable for plant populations with relatively high natural mortality (e.g., Thomas, 1991; Bunting et al., 1980).

   b) The value of p_c is the same for all control plots; also, the value of p_t is the same for all treated plots for a given season of burning. From a statistical viewpoint, this means that the only variation in the data is binomial variation (e.g., Cochran, 1943; Meyers et al., 2002). This is an ideal that may never be achieved in reality; however, application of basic principles of experimental design will be used so that experimental units (plots) within a treatment are relatively homogeneous. Continuing work on the Monte Carlo analyses summarized in this paper will include assessing the affect of "over dispersion" on inferences.

4. An example of the experimental layout for this research is given in Figure 1. In this figure, each square represents a plot that will be randomly assigned to a control or a summer burning treatment. Figure 1 shows an example with 2 replications (plots) of each treatment. An experiment with 3 replications of each treatment will have 6 plots instead of 4 plots as shown in the figure. In the figure, each letter represents a cactus plant; live plants are indicated by the letter "A"; and dead plants are indicated by the letter "D". Each plot will have n_{ij} plants.

5. Sample size formulae that recognize the binomial nature of plant mortality data (Snedecor and Cochran 1980, page 129) are based on a contingency table approach. In this formula, α, β, p_c, and p_t are specified and used in the "n" formula below:

$$n_i = \frac{[z_{\alpha/2} + z_\beta]^2 \{ p_c (1 - p_c) + p_t (1 - p_t) \}}{(p_c - p_t)^2}$$

where:

n_i is the estimated number of plants per treatment; $z_{\alpha/2}$ is the upper $\alpha/2$ percentage point from the standard normal distribution; and z_β is the upper β percentage point from the standard normal distribution. For example, suppose that the proportion of plants that die in the control treatment is 20% and the proportion of plants that die in the burned treatment is 50%. Then, for a two-tailed test of the null hypothesis that there is no difference between these two proportions with a 90% power, the "*n*" formula indicates that each treatment will require n_i = 48 plants (see Table 1).

6. An example of data collected from this experiment and its analysis are given in the appendix. These data may be analyzed one of three ways.
   a) Contingency table approach:
      Assuming that the burned plots are relatively homogeneous, and that the control plots are relatively homogeneous, these data are pooled into a 2 x 2 contingency table. The null hypothesis that there is no difference in proportion of dead plants is tested with a G test.

   b) Analysis of variance approach:
      The data in each plot are converted to percents, and then transformed with an angular transformation for a F test that tests the null hypothesis that mean (transformed) mortality does not differ between treatments. Observed means on the transformed scale are back-transformed by calculating the sin of the mean, and then squaring this result. Removal of bias follows Kendall and Stuart (1966, vol. 3).

   c) Generalized linear model approach:
      The application of a generalized linear model and its associated Wald test is motivated by the idea that plant response follows a binomial distribution, and thus the analysis should explicitly account for this response. The generalized linear model "links" the binary response to the explanatory variables through a continuous probability and a "logit" link function. The hypothesis that is tested addresses whether the probability of plant mortality differs between control and burned plants.

7. Results:

Table 1:

Suppose that a significant result is to be declared when mortality differs between treatments. This difference can be in either direction: mortality in the control treatment may be more or less than mortality in the burned treatment. This is a two-tailed alternative hypothesis. Suppose that there are two experimental plots per treatment. If the mortality in the control treatment is 5% and the mortality in

the burned treatment is 10%, then the G test will detect this difference as significant at the 5% level with a 90% power if there are 579 plants per treatment (or a total of 1158 plants in the experiment). Clearly, in order to detect such a small difference in mortality, a large sample size is required.

In another scenario, suppose that whereas mortality in the control treatment is 5%, and the mortality in the burned plots is 50%. Under these conditions, 16 plants per treatment (or a total of 32 plants) would be needed to detect this difference at the 5% significance level with a 90% power with the G test. In this case fewer plants are needed for the experiment; but this experiment, based on fewer plants, has lower power and can detect only relatively large differences between treatments. It is important to appreciate that the variance association with a binomial random variable depends in part on the mean of the variable. As the mean of the random variable approaches 0.50, the variance increases. Thus, it requires a different sample size to detect, for example, a 10% difference between treatments when this difference is between 5% and 15%, compared to when this difference is between 30% and 40%.

The above results confirm that the sample size formula is accurate. That is, in the sample size formula, we prescribed a 5% significance level, a 90% power and the specified differences in Table 1.

Observed Monte Carlo results in Table 1 indicate that the actual rejection rate of the G test was close to the nominal level when the control mortality was 5% and the burned mortalities were 50% or less (Table 1), and also when the control mortality was 20% and the burned mortalities were 60% or less.

The F test on angular-transformed data always had lower power than the corresponding G test. It is clear that with only two replications per treatment, analysis of these data via an F test in an analysis of variance has low power compared to the G test.

The power performance of the Wald test from the generalized linear model was similar to the G test in the contingency table analysis.

Table 2:

The data in Table 2 are similar to the data in Table 1 except that the null hypothesis of equality of treatments was rejected only when mortality in the burned treatment exceeded mortality in the control treatment. One-tailed significance tests have the effect of being able to detect a smaller difference with a given number of plants than a two-tailed test. For example, if a total of 32 plants are used in the experiment, then with a two-tailed test, a difference in mortality of 45% (from 5% in the control to 50% in the burned treatment) can be detected with 90% power (Table 1). However, if a one-tailed test is used, then a total of 32 plants can detect a difference in mortality of 40% (from 5% in the control to 45% in the burned treatment).

Tables 3 and 4:

Tables 3 and 4 are similar to Tables 1 and 2 except that the experiment was set up with 3 experimental units per treatment rather than 2. Although this does not affect the G test (because plots are pooled into a 2 x 2 contingency table; see Figure 2), or the performance of the Wald test, increased replication improves the performance of the F test because of increased experimental error degrees of freedom.

Recommendations

Determination of an adequate sample size for this research requires a specification of the size of the effect that is to be detected. Additionally, for binomial data, the sample size required depends not only on the difference desired to be detected, but also on the percentages involved. For example, a difference of 20% involving a control mortality of 5% and a treatment mortality of 25% requires a different sample size than a difference of 20% involving a control mortality of 20% and a treatment mortality of 50%. Thus, the sample size needed for this research depends on the size of the effect that is desired to detect and on the mortalities that will be involved, neither of which can be specified with absolute assurance.

We propose using one location for the field burning study, and a separate location for the burn barrel study. In this way, the percentage of plants of any one population used will be less (because the study will be conducted in two locations rather than in one location). Field burning 100 plants will allow us to detect a difference of 23% if control mortality if 5%, and a difference of 30% if control mortality is 20%. In our judgment, these results will be meaningful to land managers.

Control Plot 1

D A

A

A A A

Burned Plot 1

D A D

D

D D

D

Burned Plot 2

A A

D

D D

D D

Control Plot 2

D A

A

D A

A A

Figure 1. Example of field experiment with 2 plots of each of two treatments (control and burned). Each plot has 8 cacti plants. Dead plants are indicated by the letter “D”; living plants are indicated by the letter “A”.

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Table 1. Estimated samples sizes per treatment needed to detect the specified difference between hypothetical mortalities between control (unburned) and burned plots with a 5% two-tailed significance level and a 90% power. Data were analyzed with three approaches: (1) a G test in a 2 x 2 contingency table; (2) an F test in an analysis of variance after an angular transformation; and (3) a Wald test in a generalized linear model. For the contingency table approach and the generalized linear model approaches, observed power and treatment proportions are shown. For the analysis of variance, observed power (on the transformed scale), observed treatment means, back-transformed means (which are biased estimates of treatment proportions), and back-transformed means with bias removed (which are unbiased estimates of treatment proportions) are shown. All results are from N = 10,000 Monte Carlo simulations. Data are for 2 replications of each treatment. The sample size formula (see text) was used to determine sample size per treatment; these values are divided by 2 for the number of plants per plot (and rounded down to the nearest whole number if the number of plants per treatment is odd).

						Contingency Table Analysis				Analysis of Variance							Generalized Linear Model		
Hypothetical Mortality Values							Treatment proportions				Treatment means		Back-transformed to estimate proportions (biased estimates)		Unbiased estimates of proportions			Treatment proportions	
Control p_c	Burned p_t	Difference between treatments	Number of plants to be burned in experiment (n)	Number of plants per treatment [1/] (n_i)	Sample Size Per Plot (n_{ij})	Observed Power: G test	Control	Burned		Observed Power: F test	Control	Burned	Control	Burned	Control	Burned	Observed Power: Wald test	Control	Burned
0.05	0.10	0.05	1158	579	289	0.9022	0.0501	0.1001		0.4310	0.2239	0.3208	0.0497	0.0998	0.0499	0.1000	0.9078	0.0499	0.1000
0.05	0.15	0.10	368	184	92	0.9134	0.0502	0.1502		0.4249	0.2191	0.3952	0.0488	0.1492	0.0494	0.1498	0.9088	0.0498	0.1500
0.05	0.20	0.15	194	97	48	0.9075	0.0504	0.2004		0.4020	0.2096	0.4599	0.0469	0.1987	0.0484	0.1997	0.8982	0.0497	0.2000
0.05	0.25	0.20	124	62	31	0.9212	0.0504	0.2505		0.3752	0.1967	0.5192	0.0444	0.2484	0.0469	0.2498	0.9009	0.0498	0.2500
0.05	0.30	0.25	88	44	22	0.9140	0.0506	0.3007		0.3499	0.1841	0.5751	0.0420	0.2984	0.0457	0.3001	0.8936	0.0500	0.3000
0.05	0.35	0.30	66	33	16	0.9014	0.0506	0.3508		0.3291	0.1702	0.6287	0.0397	0.3486	0.0448	0.3503	0.8735	0.0503	0.3498
0.05	0.40	0.35	50	25	12	0.8909	0.0507	0.4010		0.3296	0.1579	0.6805	0.0379	0.3985	0.0443	0.4000	0.8583	0.0509	0.3998
0.05	0.45	0.40	40	20	10	0.8943	0.0509	0.4507		0.3376	0.1513	0.7330	0.0373	0.4493	0.0448	0.4503	0.8641	0.0511	0.4499

0.05	0.50	0.45	32	16	8	0.8951	0.0510	0.5012		0.3543	0.1402	0.7874	0.0362	0.5020	0.0454	0.5020	0.8155	0.0514	0.5002
0.05	0.55	0.50	26	13	6	0.8394	0.0510	0.5490		0.3771	0.1325	0.8431	0.0360	0.5539	0.0484	0.5520	0.7956	0.0515	0.5495
0.20	0.25	0.05	2922	1461	760	0.8990	0.2001	0.2501		0.4334	0.4636	0.5235	0.2000	0.2500	0.2001	0.2501	0.9067	0.2000	0.2498
0.20	0.30	0.10	778	389	194	0.8929	0.2002	0.3002		0.4307	0.4630	0.5793	0.1999	0.2999	0.2001	0.3001	0.9017	0.1998	0.3000
0.20	0.35	0.15	364	182	91	0.8951	0.2003	0.3503		0.4293	0.4620	0.6325	0.1995	0.3599	0.2000	0.3501	0.9026	0.1996	0.3500
0.20	0.40	0.20	212	106	53	0.8936	0.2005	0.4004		0.4197	0.4604	0.6841	0.1989	0.4000	0.1997	0.4002	0.8999	0.1996	0.4000
0.20	0.45	0.25	138	69	34	0.8871	0.2006	0.4506		0.4121	0.4583	0.7352	0.1982	0.4503	0.1994	0.4505	0.8897	0.1994	0.4500
0.20	0.50	0.30	96	48	24	0.8810	0.2007	0.5006		0.4005	0.4552	0.7861	0.1971	0.5006	0.1989	0.5007	0.8824	0.1993	0.5001
0.20	0.55	0.35	70	35	17	0.8730	0.2009	0.5491		0.3593	0.4498	0.8361	0.1952	0.5498	0.1980	0.5493	0.8665	0.1994	0.5502
0.20	0.60	0.40	54	27	13	0.8689	0.2012	0.5991		0.3486	0.4424	0.8899	0.1923	0.6014	0.1962	0.6001	0.8522	0.1989	0.5999
0.20	0.65	0.45	42	21	10	0.8320	0.2013	0.6493		0.3045	0.4317	0.9482	0.1882	0.6547	0.1941	0.6518	0.8285	.01989	0.6500
0.20	0.70	0.50	32	16	8	0.8418	0.2015	0.6990		0.2799	0.4208	1.0137	0.1845	0.7099	0.1926	0.7043	0.8492	0.1986	0.7000

1/ Sample size estimated by $n_i = [(z_{\alpha/2} + z_\beta)^2 \{ p_c (1- p_c) + \{ p_t (1- p_t)\}] / (p_c + p_t)^2$; see text for definition of symbols

Table 2. Estimated samples sizes per treatment needed to detect the specified difference between hypothetical mortalities between control (unburned) and burned plots with a 5% one-tailed significance level and a 90% power. Data were analyzed with three approaches: (1) a G test in a 2 x 2 contingency table; (2) an F test in an analysis of variance after an angular transformation; and (3) a Wald test in a generalized linear model. For the contingency table approach and the generalized linear model approaches, observed power and treatment proportions are shown. For the analysis of variance, observed power (on the transformed scale), observed treatment means, back-transformed means (which are biased estimates of treatment proportions), and back-transformed means with bias removed (which are unbiased estimates of treatment proportions) are shown. All results are from N = 10,000 Monte Carlo simulations. Data are for 2 replications of each treatment. The sample size formula (see text) was used to determine sample size per treatment; these values are divided by 2 for the number of plants per plot (and rounded down to the nearest whole number if the number of plants per treatment is odd).

						Contingency Table Analysis				Analysis of Variance							Generalized Linear Model		
Hypothetical Mortality Values							Treatment Proportions				Treatment Means		Back-transformed to estimate proportions (biased estimates)		Unbiased estimates of proportions			Treatment Proportions	
Control p_c	Burned p_t	Difference between treatments	Number of plants to be burned in experiment (n)	Number of plants per treatment (n_i)	Sample Size Per Plot (n_{ij})	Observed Power: G test	Control	Burned		Observed Power: F test	Control	Burned	Control	Burned	Control	Burned	Observed Power: Wald test	Control	Burned
0.05	0.10	0.05	944	472	236	0.9028	0.0501	0.1001		0.6069	0.2235	0.3205	0.0496	0.0997	0.0499	0.0999	0.9061	0.0498	0.1000
0.05	0.15	0.10	300	150	75	0.9103	0.0502	0.1502		0.5947	0.2170	0.3946	0.0483	0.1490	0.0492	0.1497	0.9065	0.0498	0.1500
0.05	0.20	0.15	160	80	40	0.9159	0.0503	0.2004		0.5779	0.2046	0.4592	0.0459	0.1985	0.0478	0.1998	0.9107	0.0497	0.2001
0.05	0.25	0.20	102	51	25	0.9101	0.505	0.2507		0.5656	0.1893	0.5180	0.0431	0.2480	0.0463	0.2498	0.9020	0.0500	0.2501
0.05	0.30	0.25	72	36	18	0.9241	0.0507	0.3007		0.5545	0.1757	0.5738	0.0406	0.2979	0.0451	0.3000	0.9106	0.0501	0.3000
0.05	0.35	0.30	54	27	13	0.9058	0.0506	0.3506		0.5350	0.1614	0.6266	0.0384	0.3474	0.0444	0.3495	0.8808	0.0509	0.3498
0.05	0.40	0.35	42	21	10	0.8969	0.0509	0.4012		0.5276	0.1510	0.6798	0.0372	0.3985	0.0448	0.4003	0.8715	0.0510	0.4000

0.05	0.45	0.40	32	16	8	0.9112	0.0510	0.4510		0.5188	0.1425	0.7312	0.0364	0.4482	0.0456	0.4494	0.8894	0.0514	0.4498
0.05	0.50	0.45	26	13	6	0.8821	0.0510	0.5013		0.4895	0.1322	0.7861	0.0359	0.5506	0.0481	0.5006	0.8485	0.0514	0.5001
0.05	0.55	0.50	22	11	5	0.8635	0.0511	0.5486		0.5360	0.1279	0.8452	0.0365	0.5547	0.0518	0.5524	0.8146	0.0502	0.5492
0.20	0.25	0.05	2382	1191	595	0.8998	0.2002	0.2501		0.6032	0.4635	0.5235	0.2000	0.2500	0.2001	0.2501	0.8951	0.1999	0.2498
0.20	0.30	0.10	634	317	158	0.8956	0.2003	0.3002		0.6028	0.4627	0.5792	0.1998	0.2999	0.2000	0.3001	0.9019	0.1998	0.2000
0.20	0.35	0.15	296	148	74	0.8957	0.2004	0.3503		0.5984	0.4615	0.6324	0.1994	0.3499	0.1999	0.3501	0.9018	0.1996	0.3500
0.20	0.40	0.20	172	86	44	0.8966	0.2005	0.4005		0.5933	0.4596	0.6840	0.1987	0.3999	0.1996	0.4002	0.9036	0.1994	0.4000
0.20	0.45	0.25	112	56	28	0.8907	0.2006	0.4506		0.5851	0.4566	0.7350	0.1975	0.4501	0.1990	0.4504	0.8907	0.1992	0.4499
0.20	0.50	0.30	80	40	20	0.8903	0.2008	0.5006		0.5732	0.4526	0.7861	0.1962	0.5007	0.1984	0.5007	0.8893	0.1992	0.5000
0.20	0.55	0.35	58	29	14	0.8768	0.2009	0.5491		0.5372	0.4443	0.8365	0.1929	0.5500	0.1965	0.5494	0.8760	0.1989	0.5500
0.20	0.60	0.40	44	22	11	0.8676	0.2014	0.5991		0.5220	0.4363	0.8908	0.1900	0.6017	0.1950	0.6001	0.8743	0.1990	0.6003
0.20	0.65	0.45	34	17	8	0.8567	0.2015	0.6491		0.4683	0.4202	0.9529	0.1842	0.6569	0.1920	0.6527	0.8614	0.1986	0.6498
0.20	0.70	0.50	26	13	6	0.8757	0.2017	0.6992		0.3855	0.4019	1.0262	0.1769	0.7158	0.1889	0.7074	0.8006	0.1989	0.6992

1/ Sample size estimated by $n_i = [(z_\alpha + z_\beta)^2 \{ p_c (1- p_c) + \{ p_t (1- p_t)\}] / (p_c + p_t)^2$; see text for definition of symbols

Table 3. Estimated samples sizes per treatment needed to detect the specified difference between hypothetical mortalities between control (unburned) and burned plots with a 5% two-tailed significance level and a 90% power. Data were analyzed with three approaches: (1) a G test in a 2 x 2 contingency table; (2) an F test in an analysis of variance after an angular transformation; and (3) a Wald test in a generalized linear model. For the contingency table approach and the generalized linear model approaches, observed power and treatment proportions are shown. For the analysis of variance, observed power (on the transformed scale), observed treatment means, back-transformed means (which are biased estimates of treatment proportions), and back-transformed means with bias removed (which are unbiased estimates of treatment proportions) are shown. All results are from N = 10,000 Monte Carlo simulations. Data are for 3 replications of each treatment. The sample size formula (see text) was used to determine sample size per treatment; these values are divided by 2 for the number of plants per plot (and rounded down to the nearest whole number if the number of plants per treatment is odd).

						Contingency Table Analysis				Analysis of Variance							Generalized Linear Model		
Hypothetical Mortality Values							Treatment proportions				Treatment means		Back-transformed to estimate proportions (unbiased estimates)		Unbiased Estimates of proportions			Treatment Proportions	
Control p_c	Burned p_t	Difference between treatments	Number of plants to be burned in experiment (n)	Number of plants per treatment (n_i)	Sample Size Per Plot (n_{ij})	Observed Power: G test	Control	Burned		Observed Power: F test	Control	Burned	Control	Burned	Control	Burned	Observed Power: Wald test	Control	Burned
0.05	0.10	0.05	1158	579	289	0.9056	0.0501	0.1002		0.6874	0.2228	0.3203	0.0492	0.0995	0.0499	0.1001	0.9030	0.0500	0.1000
0.05	0.15	0.10	368	184	92	0.9119	0.0501	0.1505		0.6807	0.2138	0.3941	0.0467	0.1484	0.0490	0.1502	0.9025	0.0499	0.1499
0.05	0.20	0.15	194	97	48	0.9074	0.0503	0.2008		0.6635	0.1971	0.4580	0.0423	0.1973	0.0472	0.2005	0.9307	0.0499	0.1998
0.05	0.25	0.20	124	62	31	0.9134	0.0503	0.2509		0.6587	0.1777	0.5160	0.0377	0.2459	0.0456	0.2503	0.8845	0.0502	0.2498
0.05	0.30	0.25	8	44	22	0.9043	0.0503	0.3017		0.6712	0.1605	0.5716	0.0339	0.2956	0.0446	0.3004	0.8721	0.0505	0.2998
0.05	0.35	0.30	66	33	16	0.9096	0.0504	0.3517		0.7016	0.1488	0.6250	0.0316	0.3453	0.0447	0.3499	0.8734	0.0509	0.3498

0.05	0.40	0.35	50	25	12	0.8938	0.0504	0.4020		0.6846	0.1335	0.6765	0.0290	0.3950	0.0458	0.3992	0.8572	0.0514	0.3998
0.05	0.45	0.40	40	20	10	0.8829	0.0507	0.4522		0.6515	0.1199	0.7287	0.0270	0.4459	0.0484	0.4487	0.7993	0.0520	0.4496
0.05	0.50	0.45	32	16	8	0.8747	0.0506	0.5023		0.6576	0.1149	0.7869	0.0267	0.5017	0.0530	0.5016	0.7650	0.0528	0.5001
0.05	0.55	0.50	26	13	6	0.8433	0.0508	0.5466		0.5922	0.1026	0.8468	0.0250	0.5564	0.0572	0.5519	0.7947	0.0532	0.5506
0.20	0.25	0.05	2922	1461	760	0.8954	0.2002	0.2499		0.6722	0.4635	0.5232	0.2000	0.2497	0.2002	0.2498	0.8988	0.2000	0.2500
0.20	0.30	0.10	778	389	194	0.8970	0.2001	0.3004		0.6763	0.4623	0.5792	0.1993	0.2999	0.1999	0.3003	0.8981	0.1999	0.2999
0.20	0.35	0.15	364	182	91	0.8981	0.2002	0.3507		0.6749	0.4606	0.6324	0.1984	0.3498	0.1997	0.3501	0.8940	0.1999	0.3499
0.20	0.40	0.20	212	106	53	0.8949	0.2002	0.4009		0.6678	0.4580	0.6840	0.1971	0.3999	0.1994	0.4006	0.8941	0.1998	0.3999
0.20	0.45	0.25	138	69	34	0.4942	0.2004	0.4512		0.6624	0.4541	0.7353	0.1951	0.4504	0.1987	0.4510	0.8890	0.1998	0.4499
0.20	0.50	0.30	96	48	24	0.8837	0.2005	0.5014		0.6431	0.4474	0.7868	0.1915	0.5014	0.1973	0.5014	0.8763	0.1999	0.4998
0.20	0.55	0.35	70	35	17	0.8663	0.2006	0.5484		0.5934	0.4389	0.8368	0.1850	0.5503	0.1944	0.5488	0.8616	0.1998	0.5502
0.20	0.60	0.40	54	27	13	0.8776	0.2007	0.5983		0.6076	0.4251	0.8927	0.1801	0.6039	0.1929	0.5998	0.8565	0.1996	0.6001
0.20	0.65	0.45	42	21	10	0.8600	0.2006	0.6479		0.5895	0.4090	0.9562	0.1720	0.6615	0.1896	0.6524	0.8570	0.1998	0.6508
0.20	0.70	0.50	32	16	8	0.8055	0.2011	0.6971		0.5364	0.3854	1.0359	0.1616	0.7262	0.1880	0.7079	0.8095	0.2001	0.7001

[1/] Sample size estimated by $n_i = [(z_{\alpha/2} + z_\beta)^2 \{ p_c (1- p_c) + \{ p_t (1- p_t)\}] / (p_c + p_t)^2$; see text for definition of symbols

Table 4. Estimated samples sizes per treatment needed to detect the specified difference between hypothetical mortalities between control (unburned) and burned plots with a 5% one-tailed significance level and a 90% power. Data were analyzed with three approaches: (1) a G test in a 2 x 2 contingency table; (2) an F test in an analysis of variance after an angular transformation; and (3) a Wald test in a generalized linear model. For the contingency table approach and the generalized linear model approaches, observed power and treatment proportions are shown. For the analysis of variance, observed power (on the transformed scale), observed treatment means, back-transformed means (which are biased estimates of treatment proportions), and back-transformed means with bias removed (which are unbiased estimates of treatment proportions) are shown. All results are from N = 10,000 Monte Carlo simulations. Data are for 2 replications of each treatment. The sample size formula (see text) was used to determine sample size per treatment; these values are divided by 2 for the number of plants per plot (and rounded down to the nearest whole number if the number of plants per treatment is odd).

						Contingency Table Analysis				Analysis of Variance							Generalized Linear Model		
Hypothetical Mortality Values							Treatment Proportions				Treatment Means		Back-transformed to estimate proportions (biased estimates)		Unbiased estimates of proportions			Treatment Proportions	
Control p_c	Burned p_t	Difference between treatments	Number of plants to be burned in experiment (n)	Number of plants per treatment (n_i)	Sample Size Per Plot (n_{ij})	Observed Power: G test	Control	Burned		Observed Power: F test	Control	Burned	Control	Burned	Control	Burned	Observed Power: Wald test	Control	Burned
0.05	0.10	0.05	944	472	236	0.9052	0.0501	0.1002		0.7790	0.2221	0.3199	0.0490	0.0994	0.0498	0.1000	0.9012	0.0500	0.0999
0.05	0.15	0.10	300	150	75	0.9136	0.0501	0.1506		0.7768	0.2009	0.3931	0.0457	0.1481	0.0485	0.1503	0.9038	0.0500	0.1499
0.05	0.20	0.15	160	80	40	0.9115	0.0502	0.2009		0.7740	0.1890	0.4562	0.0402	0.1963	0.0464	0.2004	0.9002	0.0500	0.1998
0.05	0.25	0.20	102	51	25	0.9129	0.0503	0.2514		0.7901	0.1701	0.5145	0.0360	0.2452	0.0451	0.2503	0.9041	0.0503	0.2497
0.05	0.30	0.25	72	36	18	0.9204	0.0505	0.3012		0.7940	0.1530	0.5983	0.0325	0.2932	0.0448	0.2991	0.9029	0.0508	0.2995
0.05	0.35	0.30	54	27	13	0.9179	0.0506	0.3518		0.8010	0.1391	0.6216	0.0299	0.3431	0.0454	0.3488	0.8911	0.0511	0.3497
0.05	0.40	0.35	42	21	10	0.9126	0.0506	0.4021		0.7915	0.1268	0.6739	0.0280	0.3933	0.0468	0.3982	0.8896	0.0514	0.3996

0.05	0.45	0.40	32	16	8	0.8926	0.0506	0.4521		0.7520	0.1146	0.7247	0.0266	0.4430	0.0528	0.4467	0.8631	0.0529	0.4496
0.05	0.50	0.45	26	13	6	0.8813	0.0508	0.5029		0.6967	0.1026	0.7884	0.0250	0.5032	0.0571	0.5030	0.8423	0.0532	0.4992
0.05	0.55	0.50	22	11	5	0.8295	0.0509	0.5461		0.6615	0.0960	0.8462	0.0255	0.5534	0.0706	0.5476	0.7333	0.0532	0.5496
0.20	0.25	0.05	2382	1191	595	0.8948	0.2003	0.2497		0.7631	0.4635	0.5230	0.2000	0.2497	0.2002	0.2498	0.8996	0.1999	0.2500
0.20	0.30	0.10	634	317	158	0.8975	0.2002	0.3005		0.7728	0.4620	0.5791	0.1992	0.2998	0.1999	0.3003	0.9471	0.1999	0.2999
0.20	0.35	0.15	296	148	74	0.8969	0.2002	0.3507		0.7722	0.4598	0.6321	0.1981	0.3497	0.1996	0.3505	0.8949	0.1999	0.3498
0.20	0.40	0.20	172	86	44	0.8932	0.2002	0.4010		0.7607	0.4562	0.6838	0.1961	0.3997	0.1990	0.4007	0.8868	0.1998	0.3998
0.20	0.45	0.25	112	56	28	0.8799	0.2003	0.4512		0.7499	0.4500	0.7350	0.1929	0.4502	0.1979	0.4510	0.8793	0.1997	0.4496
0.20	0.50	0.30	80	40	20	0.8909	0.2005	0.5014		0.7505	0.4414	0.7867	0.1883	0.5014	0.1959	0.5014	0.8839	0.1999	0.4997
0.20	0.55	0.35	58	29	14	0.8746	0.2007	0.5429		0.7111	0.4249	0.8374	0.1800	0.5506	0.1923	0.5486	0.8737	0.1996	0.5504
0.20	0.60	0.40	44	22	11	0.8520	0.2006	0.5979		0.7092	0.4090	0.8968	0.1702	0.6006	0.1892	0.6007	0.8501	0.1998	0.6004
0.20	0.65	0.45	34	17	8	0.8315	0.2011	0.6475		0.6654	0.3852	0.9700	0.1616	0.6701	0.1876	0.6562	0.8303	0.2001	0.6505
0.20	0.70	0.50	26	13	6	0.8782	0.2010	0.6970		0.6433	0.3657	1.0506	0.1533	0.7342	0.1863	0.7110	0.7991	0.2003	0.6999

1/

Sample size estimated by $n_i = [(z_\alpha + z_\beta)^2 \{ p_c (1- p_c) + \{ p_t (1- p_t)\}] / (p_c + p_t)^2$; see text for definition of symbols

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APPENDIX

Contingency Table Approach:

Data from Figure 1 are summarized in the 2 x 2 table below for analysis with a G test to test the equality of equality of proportions of dead plants in control and burned treatments.

Outcome	Control	Treatment
Dead	3	12
Alive	13	4
Total	16	16

G = 10.80 Tabular value = 3.841

Analysis of Variance Approach:

Data from Figure 1 are transformed and analyzed with an F test to test the hypothesis of equality of transformed mean mortality in control and burned treatments.

Original data (Y_{ij}/n_{ij}):

Replication	Control	Treatment
1	1/8	7/8
2	2/8	5/8

Transformed data: $\sin^{-1}\sqrt{(Y_{ij}/n_{ij})}$:

Replication	Control	Treatment
1	0.361367	1.209429
2	0.523598	0.911738

F = 13.29 Tabular F = 18.5

	Control	Treatment
Observed mean	0.4424819	1.0605837
Back-transformed (unbiased mean)	0.1878264	0.7577985

Generalized Linear Model Approach:

Treatment	No. of plants	No. of dead plants	Probability of mortality
Control	8	1	0.1875
Control	8	2	0.1875
Burned	8	7	0.7500
Burned	8	5	0.7500

Wald test = 8.84 Tabular value: 3.841

Appendix C: Biological Assessment USFWS: July 14, 2003

United States Department of the Interior

FISH AND WILDLIFE SERVICE
New Mexico Ecological Services Field Office
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Albuquerque, New Mexico 87113
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BUREAU OF LAND MGMT.
CARLSBAD FIELD OFFICE

July 14, 2003

Cons. #22-03-F-0078.1

Memorandum

To: Field Manager, Bureau of Land Management, Carlsbad Field Office, Carlsbad, New Mexico (Attn: Leslie Hiess)

From: State Supervisor, U.S. Fish and Wildlife Service, New Mexico Ecological Services Field Office, Albuquerque, New Mexico

Subject: Biological Opinion for Determining the Effects of Prescribed Fire on Kuenzler's Hedgehog Cactus

This document transmits the U.S. Fish and Wildlife Service's (Service) biological opinion (BO) based on our review of the proposed prescription burns and their effects on the endangered Kuenzler's hedgehog cactus (*Echinocereus fendleri* var. *kuenzleri*) (cactus) in accordance with section 7 of the Endangered Species Act (Act) of 1973, as amended (16 U.S.C. 1531 *et seq.*). Formal consultation was initiated on June 10, 2003.

This BO is based on information provided in the June 5, 2003, Biological Evaluation (BE), and other sources of information available to the Service. On July 2, 2003, we received additional information clarifying the proposed action. A complete administrative record of this consultation is on file at the New Mexico Ecological Services Field Office, Albuquerque, New Mexico.

Consultation history

In November 2002, and May 2003, a proposal was developed to use a burn barrel technique and field-scale (broadcast) burns to determine fire effects on the cactus. The proposal was to burn approximately 131 cacti. In an effort to reduce the number of cacti lost to the population, the methods were changed to combine aspects of the burn barrel technique (to determine heat impacts to individual cacti) and the broadcast burn (to determine the effect of removing vegetation around a plant). The final agreed-upon proposed action was received on July 2, 2003.

The Proposed Action

The Carlsbad Field Office (CFO) of the Bureau of Land Management (BLM) has used prescribed burns within lands it administers for several years in order to reduce fuel loading and improve vegetative diversity. In recent years, due to lack of data on the cactus' response to fire, CFO has not proposed prescribed burns within suitable or occupied cactus habitat. This policy is based on the assumption that fire would be detrimental to the cactus. There is little scientific literature on the effects of fire to this species to either support or refute this assumption. The little information available suggests that only portions of a population be allowed to burn in any single prescribed fire, and that fire be reapplied at sufficiently long temporal intervals to recover and reestablish a seed bank (Sivinski 1999).

Data gathered from the proposed project may be useful to other land management agencies in the area. The Guadalupe Ranger District (GRD) of the Lincoln National Forest has prepared a landscape scale fuels treatment program for piñon - juniper woodlands and removed approximately 62,000 acres from treatment consideration due to suitable or potentially suitable cactus habitat. The Roswell Field Office (RFO) of the BLM has an active fuel management program at Ft. Stanton, a wildland urban interface area near Ruidoso. The RFO avoids areas that may contain cactus, although they do not impose as large a buffer as the CFO or GRD. This proposed project should allow for more informed decisions regarding the use of fire as a management tool in cactus habitat. The proposed project would investigate potential effects to the cactus from prescribed fire management during a three year research project conducted by Texas Tech University.

Objectives for the proposal are to: 1) Determine the effect fire has on individual cactus and what role plant condition and adjacent fuel loading and spatial arrangement have on survivability of the cactus; 2) Determine the effect fire has on population dynamics of cactus populations; 3) Determine habitat manipulations that would potentially mitigate adverse impacts to cactus including burn windows, weather conditions, and cover density from herbaceous and shrub components; 4) Provide a complete characterization of the micro-habitats associated with cactus; 5) Publish findings to assist other land management agencies, universities and public in managing cactus habitats; and 6) Collect seeds to determine germination and establishment requirements for the cactus.

The project proposes that 13 of the 259 known plants in the Guadalupe Mountains and 48 of the 948 known plants in the Fort Stanton area be used to determine fire effects on cactus. Four plots in the Ft. Stanton area and one plot on Texas Hill are proposed for the research project.

Burn plots described in the June 5, 2003, BE are:

plot 1 - T. 10 S., R. 14 E., section 01
plot 2 - T. 10 S., R. 14 E., section 11
plot 3 - T. 09 S., R. 14 E., section 28
plot 4 - T. 10 S., R. 14 E., section 10
plot 5 - T. 22 S., R. 21 E., section 22 (identified as the burn barrel plot in the BE)

The project will use small plots (approximately 1 to 2 meter (m) (3.3 to 6.6 foot) diameter) centered around each plant that will be individually burned under natural fuel load conditions. A metal ring (30-centimeter (cm) (11.8 inches)) tall will be placed around each plant prior to burning. Each plot will be individually burned; however, if two or more plots are close enough together, they may be burned simultaneously. The prescribed burning will be conducted during the spring of 2004.

Prior to burning, all the cacti in each plot would be marked with numbered, permanent stakes. Plant size (number of stems, height and diameter of stems) would be recorded. Each plant would be photographed. Additionally, characteristics of surrounding vegetation would be described within a 3-m (3.9 foot) radius around each cactus. These data would include distance, bearing, height, basal circumference and number of stems of each plant. Ground cover characteristics (bare ground, litter, rock) would also be recorded. These data would be used to describe fuel loading, fuel arrangement surrounding each cactus and subsequent variations in fire intensity. These data would also be available to correlate plant species and density associations with cactus occurrence.

Following a treatment, each cactus would be re-photographed and re-measured. Damage to individual plants would be assessed based on actual damage to the epidermal tissue. These data would be collected within one week of burning, and monthly or bimonthly for the duration of the study. Multiple regression methods would be used to assess effects of surrounding vegetation and habitat features on subsequent growth and survival of the cactus. These effects are expected to change over the duration of the study and repeated measure analyses would be used. Control plots would be established in areas representative of the test plots. Data on plant characteristics in the control plots would be collected and re-measured concurrently with the test plots for the duration of the study.

The initial phase of the study will take three years to complete. The information gained from this research would be used for a graduate student dissertation. The information would be posted on the Fire Ecology Center, Department of Range, Wildlife and Fisheries Management, Texas Tech University website (http://www.rw.ttu.edu/fec). The annual reports would be submitted to CFO, RFO, and the Service.

This research project has funding through the Joint Fire Science Program for three years. The CFO will seek additional funding so that Texas Tech University or another research institution would be able to continue monitoring the sites to determine long-term trends and effects of fire on the cactus.

Natural fire frequency and description of the action area

Data on fire regimes suggests that prior to European settlement, low severity surface fires occurred about every 8 to 15 years (range 2 to 30 years) within Guadalupe Mountains plant communities (Cox 1999, Dahms and Geils, 1997). After settlement, the mean fire return interval (FRI) lengthened due to livestock grazing which reduced the fine fuels needed to carry fire. Fire

frequency continued to decline throughout the 20th century due to fire suppression. Most natural ignitions would have occurred in the dry season (April through June) before trees began growth for the year or in the early part of the growing season (Ahlstrand 1981).

The project area is categorized as a Piñon - Juniper Grass Mountain Standard Habitat Site following Integrated Habitat Inventory Classification. Associated plant species include sideoats grama (*Bouteloua curtipendula*), blue grama (*B. gracilis*), black grama (*B. eriopoda*), curlyleaf muhly (*Muhlenbergia setifolia*), purple three-awn (*Aristida purpurea*), beargrass (*Nolina spp.*), banana yucca (*Yucca baccata*), New Mexico agave (*Agave neomexicana*), tree cholla (*Opuntia imbricata*), lechuguilla (*A. lechuguilla*) and one seed juniper (*Juniperus monosperma*). There are several forb species found in the analysis area; however, their frequencies fluctuate based on season of year and climatic conditions. Some of the more common forb species are stickseed (*Lappula spp.*), flax (*Linum spp.*), plantain (*Plantago spp.*) and verbain (*Verbena spp.*). Many wildlife species use the general area. Nearby canyons and draws provide habitat for mammals, birds, herptofauna (reptiles and amphibians), and insects.

Conservation measures that are part of the proposed action and designed to minimize impacts to the cactus include:

1. An approved prescribed burn plan will be prepared which describes the fuel and weather parameters under which the plots will be burned.

2. It is anticipated that the minimum holding forces required for the burning will be a BLM engine with a hose to the plot, along with qualified personnel with bladder bags and handtools, such as flappers. Some plots may require prep work such as using a weed whacker to reduce grass heights and a leaf rake to create a mineral line.

Species Description, Life History, and Populations Dynamics

Horst Kuenzler collected the type specimen of the cactus in 1961. In 1976, the cactus was identified as *Echinocereus kuenzleri* (Castetter et al. 1976). Prior to 1976, the cactus was known as *Echinocereus psudohempelii*, and was included in the 1975 plant notice of review (40 FR 27824) as *Echinocereus hempelii*. When *Echinocereus kuenzleri* was listed as endangered in 1979, many experts in the taxon believed it was a subspecies or variant of *Echinocereus fendleri*, and not a separate species. With Dr. Lyman Benson's 1982 publication, The Cacti of the United States and Canada, the name *Echinocereus fendleri var. kuenzleri* became accepted and was changed in the July 1984 list of Endangered and Threatened Wildlife and Plants (Benson 1982).

A single cactus may be single stemmed or branched. The stems are normally 15cm (6 inches (in)) long and 10 cm (4 in) wide with 9 to 12 prominent ribs with tubercles from which spine clusters originate. The spines are not round, bulbous, and fused at the base. Central spines are usually absent, while radial spines vary from two to six and are variable in size up to 2.5 cm (1 in) long. (Castetter *et al.* 1976).

Flowers are large for the size of the plant, up to 11 cm (4 in) long (Taylor 1985). Fruits are bright red when mature, ovoid to cylindrical, may be over 5 cm (2 inches) long, and are spiny with miniature versions of the stem spines. Seeds are black and pitted. Characteristics used to separate Kuenzler's hedgehog cactus from the other cacti in its range are the few, contorted, white, chalky textured spines and large, magenta flowers (Service 1985).

Typical cactus habitat is the lower fringes of the pinyon-juniper woodland. The dominant tree being one-seed juniper, although the species can be found associated with alligator-bark juniper (*Juniperus deppeana*) and piñon pine (*Pinus edulis*). Soils can be best described as skeletal decomposed limestone (Service 1985).

In addition to one-seed juniper, alligator-bark juniper, and piñon pine, other common plants associated with cactus include yerba (*Baccharis pternoides*), blue grama grass, plains lovegrass (*Eragrostis intermedia*), buckwheat (*Eriogonum havardii*), goldman's silktassel (*Garrya ovata ssp. goldmanii*), false pennyroyal (*Hedeoma pulchella*), bladderpod (*Lesquerella valida*), pincushion cactus (*Mammillaria heyderi*), and sage (*Salvia earlei*) (Service 1985).

Status and Distribution

The cactus was proposed for listing as endangered on June 16, 1976, (41 FR 24523) and was federally listed as endangered on October 29, 1979, with no critical habitat designated due to the threat of collection (44 FR 61924). The recovery plan for the cactus identified two populations of cacti in the Rio Hondo and Rio Peñasco drainages in Lincoln County (Service 1985). There are currently seven locales where the cactus is documented in New Mexico. These areas are found in Chaves, Eddy, Lincoln, and Otero Counties (Blue Earth Ecological Consultants, 2002). The total number of known plants found on U.S. Forest Service and BLM lands is approximately 1,600 (Chauvin et al. 2001). Although the cactus is also present on Tribal, private, and State lands, the majority of known plants reside on federally owned lands.

Environmental Baseline

Regulations implementing the Act (50 CFR 402.02) define the environmental baseline as the past and present impacts of all Federal, State, or private actions and other human activities in the action area, the anticipated impacts of all proposed Federal actions in the action area that have undergone section 7 consultation, and the impacts of State and private actions that are contemporaneous with the consultation in progress. The environmental baseline defines the current status of the species and its habitat in the action area to provide a platform from which to assess the effects of the action now under consultation.

Status of the species within the Action Area

Within the Guadalupe Mountains, the cactus has been found to range from 1,584 to 2,011 m (5,200 - 6,600 feet) on gentle, gravelly to rocky slopes (typically less than 5 percent) and benches. Habitat for the species occurs on the lower fringes of the piñon - juniper woodland on

skeletal soils of limestone outcrop. The soil type the plants are most frequently found on is the Deama soils (0 to 5 percent slope). The Deama soil is described as very dark grayish brown of limestone origin, with a weak granular structure, non-plastic, strongly calcareous and moderately alkaline (USDA Soil Survey, 1972).

The majority of Ft. Stanton Kuenzler's hedgehog cacti are found between 2,011 and 2,103 m (6,600 - 6,900 feet) on open southeast aspects. They are typically found on the upper one-third of 20 percent slopes (DeBruin 1996). Plants are found on soils with an igneous substrate. Plants have not been found on the east side of the Ft. Stanton area where the soils are of limestone origin (DeBruin 1996).

Factors Affecting the Species in the Action Area

Factors that may be affecting the cactus within the action area are collection, ground disturbance associated with road construction or maintenance, and fire. Ground disturbance (e.g., road construction) may occasionally destroy cacti or suitable cacti habitat. Livestock grazing is not currently affecting the cacti that are proposed for either burning or as controls. Ft. Stanton is not open to grazing, and the Texas Hill plot is too distant and steep to be attractive to cattle.

Effects of the Action

The proposed prescribed burns may destroy up to 61 cacti. This represents 3.8 percent of the known population. We do not anticipate burning any cacti unintentionally. The proposed safeguards against fire escaping should adequately protect the cacti outside the scope of this project.

The presence of survey stakes, researchers, burn circles, etc, may educate collectors to the presence of this rare cacti, and subsequently increase the collection pressure on this population. The study area is not currently grazed by livestock. There is no plan to graze the Ft. Stanton population. The Texas Hill plot is within a grazing allotment, but the slope and arid nature of the area where the cactus is found is not attractive to cattle, and no grazing is expected as a result of the proposed action.

Conclusion

After reviewing the current status of the cactus, the environmental baseline for the action area, the effects of the proposed prescription burns, it is the Service's biological opinion that the action, as proposed, is not likely to jeopardize the continued existence of this species. No critical habitat has been designated for this species, therefore none will be affected.

Incidental Take Statement

Taking that is incidental to, and not intended as part of the agency action, generally do not apply to listed plant species. However, limited protection of plants from take is provided to the extent

that the Act prohibits the removal and reduction to possession of federally endangered plants or the malicious damage of such plants on areas under Federal jurisdiction, or the destruction of endangered plants on non-Federal areas in violation of State law or regulation or in the course of any violation of a State criminal trespass law.

Conservation Recommendations

1. Any suspicious collection related activity within the project area should be reported to BLM and Service law enforcement: BLM law enforcement; (505) 234-5914; or Service law enforcement; (505) 346-7828.

2. The BLM should ensure that employees, students, and others associated with this project know how to report illegal collecting activities.

3. In order to protect these cacti from collectors, the BLM should keep the proposed project activities (including identification and marking plants, burning, and monitoring) inconspicuous.

Reinitiation

This concludes formal consultation on the actions outlined in the request for consultation on the effects of prescribed fire on the cactus. As provided in 50 CFR 402.16, reinitiating formal consultation is necessary where discretionary Federal agency involvement or control over the action has been retained (or is authorized by law) and if: (1) new information reveals effects of the agency action that may affect this species in a manner or to an extent not considered in this BO; (2) the agency action is subsequently modified in a manner that causes an effect to the cactus not considered in this BO; or (3) a new species is listed or critical habitat is designated that may be affected by the action.

In future communications regarding this consultation, please refer to consultation #2-22-03-F-0078. If you have any questions, please contact Bill Ostheimer at the letterhead address or at (505) 761-4737.

Joy E. Nicholopoulos

Joy E. Nicholopoulos

cc:
Director, New Mexico Department of Game and Fish, Santa Fe, New Mexico
Director, New Mexico Energy, Minerals, and Natural Resources Department, Forestry Division, Santa Fe, New Mexico

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Appendix D: USFWS July 25, 2003 Letter to Texas Tech University Clarifying its Biological Assessment

United States Department of the Interior

FISH AND WILDLIFE SERVICE
New Mexico Ecological Services Field Office
2105 Osuna NE
Albuquerque, New Mexico 87113
Phone: (505) 346-2525 Fax: (505) 346-2542

July 25, 2003

Cons. #2-22-03-F-0078.1

Dr. David Wester
Department of Range, Wildlife, and
Fisheries Management
College of Agricultural Sciences and
Natural Resources
Texas Tech University
Lubbock, Texas 79409-2125

Dear Dr. Wester:

This letter acknowledges the U. S. Fish and Wildlife Service's (Service) July 21, 2003, receipt of your July 18, 2003, letter clarifying the proposed prescribed burn project on Bureau of Land Management lands near the Guadalupe Mountains. We have completed a biological opinion for impacts on Kuenzler's hedgehog cactus *(Echinocereus fendleri var. Kuenzleri)* (cactus) dated July 14, 2003, which allows 13 of the 259 known plants in the Guadalupe Mountains and 48 of the 948 known plants in the Fort Stanton area be used to determine fire effects on the cactus.

Should you identify additional, previously unknown cacti, please contact us to discuss incorporating up to five percent of those cacti found into the prescribed burn study. If you have any questions or concerns about this consultation or the consultation process in general, please feel free to contact me or Bill Ostheimer of this office at (505) 761-4737.

Sincerely,

Joy E. Nicholopoulos

Joy E. Nicholopoulos
State Supervisor

cc:
Field Office Manager, Bureau of Land Management, Carlsbad Field Office, Carlsbad, NM
(Attn: John Sherman and Ty Bryson)

Appendix E: Texas Tech University's Request for Additional Plants November 7, 2003
(attachments to the letter not included)

TEXAS TECH
UNIVERSITY
Range, Wildlife, and Fisheries Management
Phone: 742-2841
Fax: 742-2280
MS 2125

November 7, 2003

Dr. Joy Nicholopoulos
U.S. Department of the Interior
Fish and Wildlife Service
New Mexico Ecological Services Field Office
2105 Osuna NE
Albuquerque, NM 87113

Dear Dr. Nicholopolous:

This letter addresses the research project that we are conducting on fire effects on Kuenzler's hedgehog cactus. I have enclosed several annotated aerial photographs as well as some GPS locational data to supplement this letter.

This summer and autumn, we began inventorying locations of plants in the Ft. Stanton area in preparation for field application of burning treatments this coming spring. In our work to date, we have thoroughly surveyed populations 10 and 27 (for which we have permits) as well as populations 1 and 15 (for which we are not currently permitted); populations 1 and 15 are extensive and contiguous, and we have not completed a thorough survey of this area. In the course of these surveys, we encountered many more plants than were previously known.

The accompanying aerial photographs show the locations of the populations we have surveyed to date. On these maps, we have used red dots to indicate previously-known plants and yellow dots to indicate new, additional plants. Of course, we do not know, for a given plant in the field that we have located, whether it was included in the BLM's original data base or is a new record (the BLM does not have GPS locations). Nevertheless, the use of these two colors of dots illustrates how many plants were originally known and how many are new records. The accompanying printout lists the GPS locations of all the plants we have encountered in the field. In tabular summary:

Populations	BLM's no. of known plants	Additional plants found	Updated total no. of known plants
1 and 15	127	57	184
10	23	58	81
27	26	441	467
New population		38	38

Total	176	594	770

Thus, whereas the BLM records show that there were 176 plants in these four study areas, we have documented and acquired GPS locations for a total of 770 plants, which represents a 338% increase in the number of known plants. This increase includes documentation of a previously-unknown population of 38 plants.

BLM records indicate a known population of 948 plants for the Ft. Stanton unit as a whole. If we assume that the increase in the number of plants we have documented in our survey can be applied to the Ft. Stanton unit as a whole, then we estimate that this area supports a total of 4148 cactus plants.

We are currently permitted to use 48 plants for our burning treatments (memorandum from your office to the Carlsbad Field Office, BLM, dated 14 July, 2003); this represents 5% of the known population. You indicated to Dr. Britton in a phone conversation on 23 June, 2003 that we may have 5% of the additional plants that we can document.

Pursuant to your letter to me dated 25 July 2003, I would like to formally request that we be permitted an additional 48 plants in the Ft. Stanton area to incorporate into our research. With these additional plants, we will be able to expand the scope of our research. In particular, with the 48 plants we are currently permitted, it is possible to conduct burning in only one season. The original proposal funded by the Joint Fire Science Program specified that we would have several seasons of burning. If you grant us permission to include an additional 48 plants, we will be able to include a second season of burning. It is our strong opinion that the inclusion of an additional season of burning will considerably enhance the value of our research.

We would be happy to visit with you on the phone, in your office in Albuquerque, or even in the field in Ft. Stanton if you wish, to discuss our request for an additional 48 plants to use in our research.

Please contact me if I can provide any additional information. I realize that you have many demands on your time. However, it will be important for us to know at your earliest convenience if we can expand the scope of our research. I look forward to hearing from you.

Sincerely,

David B. Wester
Professor
Range, Wildlife, and Fisheries Mgt.

enc: Aerial photos of Ft. Stanton; list of GPS locations

Appendix F: USFWS November 19, 2003 Letter to Texas Tech University Granting Request For Additional Plants

United States Department of the Interior

FISH AND WILDLIFE SERVICE
New Mexico Ecological Services Field Office
2105 Osuna NE
Albuquerque, New Mexico 87113
Phone: (505) 346-2525 Fax: (505) 346-2542

November 19, 2003

Cons. #2-22-03-F-0078.2

Dr. David Wester
Department of Range, Wildlife,
and Fisheries Management
College of Agricultural Sciences
and Natural Resources
Texas Tech University
Lubbock, Texas 79409-2125

Dear Dr. Wester:

This letter acknowledges the U. S. Fish and Wildlife Service's (Service) November 10, 2003, receipt of your November 7, 2003, letter requesting an additional 48 Kuenzler's hedgehog cactus (*Echinocereus fendleri var. Kuenzleri*) (cactus) be included in the proposed prescribed burn project on Bureau of Land Management (BLM) lands near the Guadalupe Mountains. We completed a biological opinion on July 14, 2003, which allowed 13 of the 259 known plants in the Guadalupe Mountains and 48 of the 948 known plants in the Fort Stanton area be used to determine fire effects on the cactus. Since then, you have discovered 594 previously unknown cacti, and one unknown population, within the prescribed burn study area. Extrapolating from the cacti found within the study area, you estimate the Ft. Stanton area to contain 4,148 cacti, and have requested 48 additional cacti be included in the prescribed burn project.

The addition of 48 cacti from the Ft. Stanton population will not change the conclusion of our biological opinion, and the information gathered by adding a second burning season will help further recovery of the cactus. Therefore, we shall amend the biological opinion to include 48 additional cacti. If you have any questions or concerns about this consultation or the consultation process in general, please feel free to contact me or Bill Ostheimer of this office at (505) 761-4737.

Sincerely,

Brian Hanson

for Joy E. Nicholopoulos
State Supervisor

cc:
Field Office Manager, Bureau of Land Management, Carlsbad Field Office, Carlsbad, NM
(Attn: John Sherman and Ty Bryson)

Appendix G: Permission from USFWS to Use Nursery-Purchased Plants

-----Original Message-----
From: Joy_Nicholopoulos@fws.gov [mailto:Joy_Nicholopoulos@fws.gov]
Sent: Monday, April 11, 2005 9:28 AM
To: Wester, David
Subject: Re: Purchase of cacti from a nursery

Dr. Wester-

Please consider this e-mail as official notification from the U.S. Fish and Wildlife Service that the purchase of federally listed plants that were propagated by a commercial nursery and any ultimate harm or destruction to those propagated plants does not constitute a violation of the Endangered Species Act.

Thank you for your careful consideration of the ESA, and good luck with your cactus burn study. We eagerly anticipate your findings. If I can be of assistance in any way to you or your students, please do not hesitate to contact me.

Thank you,
Joy

Joy E. Nicholopoulos, Ph.D.
New Mexico State Administrator
U.S. Fish and Wildlife Service
505/761-4706

"Wester, David"
<david.wester@tt u.edu>
To: <Joy_Nicholopoulos@fws.gov>
cc:
Subject: Purchase of cacti from a nursery
04/07/2005 12:26 PM

Dear Dr. Nicholopoulos:

Pursuant to our recent phone call, I have before me a letter from the Manager of "Little Red Riding Hood" Nursery here in Lubbock which states:

> "The hedgehog cactus (Echinocereus kuenzleri) that we have received as requested came from one of our reputable growers. Our growers propagate their plants by seed or other asexual means. We assure you that to the best of our knowledge these plants were not harvested. If there are any further concerns please let us know and we will do our best to address them."
>
> Signed,
>
> Brent Wilkins"

The purchase of these plants from this nursery will contribute significantly to our research on the effects of fire on Kuenzler's cactus. With this e-mail, may I ask you if there are any problems with us

purchasing these plants for our research?

Thanks in advance.

Sincerely,
David B. Wester
Professor
Range, Wildlife, and Fisheries Mgt.
Texas Tech University
Lubbock, Tx
Phone: 806 742 2843
FAX: 806 742 2280

Appendix H: Weather Conditions During Burning of Greenhouse-Grown Plants in Lubbock

Lubbock 3WNW-TTU Data from 06/11/2007

Max/Min = 83.8/67.6 F Max Wind = 25.2 mph @ 06:50 PM Total rain = 0.00 inches
Maximum Sustained Wind = 17.3 mph / 143 deg @ 05:30 PM
Maximum Daytime High = 83.8 occurred at 03:50 PM

TIME (CDT)	TEMP RAIN? (F) 6ft	DEW POINT	---WIND------ DIR (MPH	SPD MPH)	GUST	ALTIMITER SETTING (INCHES)	RH %	RAIN (IN)	SOLAR RADIATION VALUE	Temp (F)	Temp (F)	Delta T 6.5ft 30ft 6.5-30ft (F)
05:05 PM	82	66	136	13	18	29.95	59	0	468	81.7	82.1	-0.4
05:00 PM	82	66	139	11	18	29.95	60	0	460	81.5	81.9	-0.5
04:55 PM	82	66	144	14	19	29.96	59	0	469	81.3	81.8	-0.6
04:50 PM	82	66	141	13	18	29.96	59	0	421	81.3	81.8	-0.6
04:45 PM	82	65	149	13	20	29.96	59	0	397	81.1	81.7	-0.6
04:40 PM	82	65	140	11	16	29.96	60	0	386	80.9	81.5	-0.6
04:35 PM	82	65	150	13	18	29.96	58	0	406	80.9	81.5	-0.6
04:30 PM	82	65	143	12	18	29.96	58	0	385	81.0	81.5	-0.5
04:25 PM	82	65	152	13	18	29.96	58	0	473	81.1	81.3	-0.3
04:20 PM	83	66	142	12	18	29.96	58	0	560	82.2	81.9	0.3
04:15 PM	82	66	131	11	14	29.96	60	0	812	81.1	81.4	-0.4
04:10 PM	81	65	126	12	17	29.96	59	0	299	80.5	80.9	-0.5
04:05 PM	83	66	127	12	17	29.96	59	0	493	81.6	81.4	0.1
04:00 PM	83	66	140	11	21	29.97	59	0	672	81.4	81.2	0.2
03:55 PM	83	66	146	13	18	29.97	58	0	696	81.6	81.3	0.4
03:50 PM	84	67	129	12	19	29.97	59	0	940	82.7	82.0	0.7
03:45 PM	83	67	149	11	18	29.97	59	0	970	82.0	81.4	0.6
03:40 PM	83	66	160	15	19	29.97	59	0	987	81.6	81.1	0.5
03:35 PM	83	67	151	12	19	29.97	59	0	862	82.1	81.4	0.7
03:30 PM	83	67	146	11	18	29.97	61	0	996	82.1	81.4	0.7
03:25 PM	83	67	147	12	16	29.96	60	0	1018	81.5	81.0	0.5
03:20 PM	83	67	131	10	17	29.97	59	0	802	81.8	81.1	0.7
03:15 PM	83	67	148	12	16	29.97	61	0	1044	81.6	80.9	0.7
03:10 PM	82	67	134	11	18	29.97	62	0	930	81.4	80.8	0.6
03:05 PM	82	67	143	12	16	29.97	62	0	916	81.0	80.4	0.5
03:00 PM	82	67	130	12	17	29.97	62	0	719	80.8	80.0	0.8
02:55 PM	82	67	149	9	16	29.97	63	0	759	80.9	80.3	0.5
02:50 PM	83	68	153	10	14	29.97	62	0	983	81.7	80.7	1.0
02:45 PM	82	68	124	10	15	29.97	63	0	1072	81.6	80.8	0.8
02:40 PM	82	68	147	9	14	29.98	64	0	828	80.6	80.1	0.5

02:35 PM	82	68	142	9	13	29.98	64	0	780	80.9	80.2	0.7
02:30 PM	82	68	138	11	17	29.98	64	0	777	80.6	80.0	0.7
02:25 PM	81	67	151	11	13	29.99	65	0	926	80.2	79.9	0.4
02:20 PM	81	67	124	11	16	29.99	64	0	428	79.8	79.4	0.4
02:15 PM	82	68	139	11	17	29.99	64	0	930	80.9	80.0	1.0
02:10 PM	81	68	136	11	15	29.99	66	0	783	80.2	79.7	0.5
02:05 PM	82	68	135	11	16	29.99	65	0	812	81.2	80.3	0.9
02:00 PM	82	68	140	9	13	29.99	66	0	749	80.7	80.0	0.6
01:55 PM	81	67	141	8	13	29.99	64	0	646	80.2	79.5	0.7
01:50 PM	82	67	139	11	14	29.99	63	0	1025	80.7	79.6	1.2
01:45 PM	82	68	137	11	16	30.00	64	0	1096	80.9	79.5	1.3
01:40 PM	82	67	144	9	14	30.00	63	0	1078	80.8	79.6	1.2
01:35 PM	82	67	145	10	14	30.00	63	0	1084	80.7	79.6	1.1
01:30 PM	82	67	132	10	14	30.00	64	0	1055	80.8	79.7	1.1
01:25 PM	82	68	141	10	13	30.00	64	0	1058	80.7	79.7	1.0
01:20 PM	82	68	133	8	14	30.00	64	0	1051	80.9	79.6	1.3
01:15 PM	81	69	146	6	10	30.00	68	0	976	80.5	79.6	0.8
01:10 PM	81	68	154	10	14	30.01	66	0	951	79.8	78.8	1.0
01:05 PM	81	68	144	7	12	30.01	67	0	736	80.1	79.1	1.0
01:00 PM	80	68	147	8	13	30.01	68	0	919	79.5	78.7	0.8

Data are a series of observations taken every 5 minutes at this West Texas Mesonet Site...

83.8 F - Maximum Temperature occurred at 03:50 PM
67.6 F - Minimum Temperature occurred at 06:30 AM
25.2 mph - Highest Wind Gust occurred at 06:50 PM
95.0 % - Maximum Rel. Humidity occurred at 06:55 AM
58.0 % - Minimum Rel. Humidity occurred at 04:35 PM
68.9 F - Maximum Dew Point Temp occurred at 01:15 PM
59.8 F - Minimum Dew Point Temp occurred at 12:45 AM

Notes: Delta T 2m-9m is the difference in temperature between the bottom and top of the tower (2meters and 9meters). Negative values of DeltaT indicate an inversion. RedFlag - indicates times with the average wind speed is > 25mph and RH < 15% at the same time. Critical Fire Danger.

Lubbock 3WNW-TTU Data from 06/13/2007

Max/Min = 83.2/63.5 F Max Wind = 21.1 mph @ 03:00 PM Total rain = 0.00 inches
Maximum Sustained Wind = 13.8 mph / 187 deg @ 09:30 AM
Maximum Daytime High = 83.2 occurred at 03:40 PM

TIME (CDT)	TEMP RAIN? (F) 6ft	DEW POINT	---WIND------ DIR (MPH	SPD MPH)	GUST	ALTIMITER SETTING (INCHES)	RH %	RAIN (IN)	SOLAR RADIATION VALUE	Temp (F)	Temp 6.5ft (F)	Delta T 30ft 6.5-30ft (F)
11:50 AM	77	58	321	11	15	29.99	53	0	893	76.2	75.6	0.6
11:45 AM	76	58	303	10	15	29.99	53	0	887	75.9	75.1	0.8
11:40 AM	76	57	302	11	16	29.99	52	0	876	75.7	74.8	0.9
11:35 AM	76	58	299	11	16	29.99	53	0	864	75.6	74.8	0.8
11:30 AM	77	57	298	10	15	29.99	53	0	854	76.0	75.0	1.1
11:25 AM	76	58	287	10	15	29.98	54	0	842	75.8	74.9	1.0
11:20 AM	76	57	285	11	15	29.98	54	0	830	75.5	74.5	1.0
11:15 AM	76	57	295	10	14	29.98	53	0	820	75.1	74.0	1.1
11:10 AM	76	57	286	11	16	29.98	53	0	807	75.0	73.7	1.2
11:05 AM	75	57	295	10	15	29.98	55	0	793	74.6	73.8	0.8
11:00 AM	75	57	306	13	17	29.98	54	0	779	74.6	73.5	1.0
10:55 AM	76	57	291	11	15	29.98	53	0	769	75.2	74.1	1.1
10:50 AM	75	57	288	11	15	29.98	53	0	756	74.8	73.8	1.0

Data are a series of observations taken every 5 minutes at this West Texas Mesonet Site...

83.2 F - Maximum Temperature occurred at 03:40 PM
63.5 F - Minimum Temperature occurred at 06:50 AM
21.1 mph - Highest Wind Gust occurred at 03:00 PM
94.0 % - Maximum Rel. Humidity occurred at 05:40 AM
35.0 % - Minimum Rel. Humidity occurred at 06:45 PM
63.7 F - Maximum Dew Point Temp occurred at 04:10 AM
51.2 F - Minimum Dew Point Temp occurred at 07:20 PM

Notes: Delta T 2m-9m is the difference in temperature between the bottom and top of the tower (2meters and 9meters). Negative values of DeltaT indicate an inversion. RedFlag - indicates times with the average wind speed is > 25mph and RH < 15% at the same time. Critical Fire Danger.

Lubbock 3WNW-TTU Data from 06/18/2007

Max/Min = 98.1/68.8 F Max Wind = 27.4 mph @ 08:35 AM Total rain = 0.00 inches
Maximum Sustained Wind = 19.6 mph / 191 deg @ 08:20 AM
Maximum Daytime High = 98.1 occurred at 06:10 PM

TIME (CDT)	TEMP RAIN? (F) 6ft	DEW POINT	---WIND------ DIR (MPH	SPD MPH)	GUST	ALTIMITER SETTING (INCHES)	RH %	RAIN (IN)	SOLAR RADIATION VALUE	Temp 6.5ft (F)	Temp 30ft (F)	Delta T 6.5-30ft (F)
04:30 PM	97	53	311	8	12	29.82	24	0	804	95.8	95.4	0.4
04:25 PM	97	53	282	8	14	29.82	24	0	815	95.6	95.1	0.5
04:20 PM	97	53	298	7	13	29.82	23	0	829	95.7	95.1	0.6
04:15 PM	96	54	336	4	11	29.82	24	0	836	95.5	95.2	0.3
04:10 PM	97	55	326	8	13	29.82	26	0	841	95.5	94.7	0.8
04:05 PM	96	53	295	6	10	29.82	24	0	857	95.6	94.7	0.9
04:00 PM	96	53	318	6	9	29.82	24	0	865	95.0	94.4	0.6
03:55 PM	96	53	298	9	12	29.82	24	0	877	95.4	94.2	1.1
03:50 PM	96	56	294	6	10	29.82	26	0	889	95.7	94.7	1.0
03:45 PM	96	56	291	7	14	29.82	28	0	892	94.8	94.2	0.6
03:40 PM	95	54	300	4	10	29.83	26	0	902	94.3	93.6	0.7
03:35 PM	95	55	292	6	10	29.83	27	0	913	94.1	93.2	0.9
03:30 PM	95	56	307	8	13	29.83	28	0	921	93.9	92.8	1.1
03:25 PM	95	54	303	6	10	29.83	26	0	929	93.8	93.0	0.8
03:20 PM	95	55	346	6	11	29.83	27	0	936	93.6	92.6	1.0
03:15 PM	95	56	295	7	10	29.83	28	0	948	93.6	92.6	1.0
03:10 PM	94	55	309	6	9	29.83	27	0	903	93.2	92.4	0.8
03:05 PM	94	54	313	5	10	29.83	27	0	960	93.2	92.0	1.1
03:00 PM	94	56	322	6	8	29.83	28	0	967	93.0	91.9	1.1
02:55 PM	93	55	333	6	9	29.83	28	0	972	92.5	91.7	0.9
02:50 PM	93	54	344	6	10	29.83	28	0	981	91.9	91.1	0.8
02:45 PM	93	55	330	8	11	29.83	29	0	985	92.0	91.0	1.0
02:40 PM	93	55	312	5	9	29.83	28	0	990	92.0	91.1	0.9
02:35 PM	92	54	321	6	11	29.83	28	0	1000	91.4	90.6	0.7
02:30 PM	93	55	336	7	11	29.83	29	0	1000	91.9	91.1	0.7
02:25 PM	92	54	343	4	7	29.83	28	0	1002	91.3	90.7	0.6
02:20 PM	92	54	307	6	10	29.83	28	0	1009	91.2	90.1	1.2
02:15 PM	92	54	346	8	12	29.83	28	0	1014	91.1	90.1	1.0

02:10 PM	92	53	345	9	14	29.83	28	0	1014	90.8	89.5	1.2
02:05 PM	92	54	332	8	14	29.83	29	0	1015	91.2	89.8	1.4
02:00 PM	92	54	287	8	12	29.83	29	0	1016	91.1	89.7	1.4

Data are a series of observations taken every 5 minutes at this West Texas Mesonet Site...

98.1 F - Maximum Temperature occurred at 06:10 PM
68.8 F - Minimum Temperature occurred at 06:45 AM
27.4 mph - Highest Wind Gust occurred at 08:35 AM
92.0 % - Maximum Rel. Humidity occurred at 07:35 AM
19.0 % - Minimum Rel. Humidity occurred at 05:10 PM
66.5 F - Maximum Dew Point Temp occurred at 09:05 AM
48.6 F - Minimum Dew Point Temp occurred at 05:10 PM

Notes: Delta T 2m-9m is the difference in temperature between the bottom and top of the tower (2meters and 9meters). Negative values of DeltaT indicate an inversion. RedFlag - indicates times with the average wind speed is > 25mph and RH < 15% at the same time. Critical Fire Danger.

Lubbock 3WNW-TTU Data from 06/19/2007

Max/Min = 96.8/62.1 F Max Wind = 27.9 mph @ 11:25 PM Total rain = 0.15 inches
Maximum Sustained Wind = 18.4 mph / 359 deg @ 11:20 PM
Maximum Daytime High = 96.8 occurred at 04:25 PM

TIME (CDT)	TEMP RAIN? 6ft (F)	DEW POINT	---WIND------ DIR (MPH	SPD MPH)	GUST	ALTIMITER SETTING (INCHES)	RH %	RAIN (IN)	SOLAR RADIATION VALUE	Temp (F)	Temp (F)	Delta T 6.5ft 30ft 6.5-30ft (F)
05:05 PM	94	59	137	13	18	30.04	32	0	404	93.0	93.3	-0.3
03:55 PM	96	60	128	12	17	30.05	32	0	859	94.6	93.6	1.0
03:50 PM	95	61	145	12	19	30.05	33	0	858	94.2	93.2	1.0
03:45 PM	95	61	136	12	16	30.05	33	0	854	94.3	93.4	0.9
03:40 PM	96	61	127	13	19	30.05	33	0	900	94.1	93.1	1.1
03:35 PM	96	61	149	14	20	30.05	33	0	906	94.3	93.4	0.9
03:30 PM	96	61	157	12	18	30.05	32	0	912	94.5	93.5	1.0
03:25 PM	96	62	146	11	22	30.05	34	0	916	94.5	93.5	1.0
03:20 PM	96	61	136	13	17	30.05	33	0	930	94.4	93.1	1.2
03:15 PM	95	60	132	11	17	30.05	32	0	936	93.9	92.9	1.0
03:10 PM	95	60	141	13	19	30.06	31	0	893	93.9	92.6	1.4
03:05 PM	95	58	142	12	18	30.06	30	0	953	94.3	93.1	1.2
03:00 PM	95	58	134	13	19	30.06	30	0	956	94.1	92.9	1.2
02:55 PM	95	58	132	12	20	30.06	29	0	963	94.2	93.1	1.1
02:50 PM	95	57	145	13	18	30.06	29	0	969	93.9	92.7	1.2
02:45 PM	95	58	135	11	17	30.06	30	0	969	93.5	92.7	0.8
02:40 PM	95	59	153	11	16	30.06	31	0	973	93.8	92.9	1.0
02:35 PM	94	60	152	11	16	30.06	33	0	970	93.0	91.8	1.2
02:30 PM	94	61	145	12	17	30.07	35	0	973	93.0	91.8	1.3
02:25 PM	94	62	134	10	14	30.07	36	0	971	92.6	91.3	1.3
02:20 PM	93	63	146	11	17	30.07	38	0	974	92.4	91.1	1.4
02:15 PM	93	63	144	11	19	30.07	38	0	981	91.7	90.3	1.4
02:10 PM	92	64	136	13	19	30.07	40	0	980	91.4	90.0	1.4
02:05 PM	92	65	120	11	16	30.07	41	0	981	91.2	90.1	1.1
02:00 PM	92	65	138	11	18	30.07	42	0	981	91.0	89.6	1.5
01:55 PM	92	66	131	13	18	30.07	44	0	980	90.7	88.9	1.8
01:50 PM	92	66	143	12	19	30.07	44	0	981	90.9	89.4	1.5
01:45 PM	92	66	127	12	18	30.07	45	0	980	90.4	88.9	1.6
01:40 PM	92	67	136	12	17	30.07	45	0	976	91.1	89.5	1.5
01:35 PM	92	67	149	13	18	30.07	45	0	975	90.9	89.3	1.6

01:30 PM	91	67	137	11	20	30.07	47	0	969	90.6	89.3	1.3
01:25 PM	91	67	130	9	15	30.07	47	0	967	90.1	88.8	1.3
01:20 PM	90	67	114	11	15	30.08	48	0	965	89.5	88.1	1.3
01:15 PM	91	67	115	11	16	30.08	47	0	965	89.7	88.2	1.5
01:10 PM	91	67	121	9	15	30.08	47	0	958	89.9	88.5	1.4
01:05 PM	91	68	136	10	17	30.07	49	0	957	89.8	88.5	1.3
01:00 PM	90	67	132	10	15	30.07	49	0	954	88.8	87.5	1.3
12:55 PM	90	67	140	12	18	30.07	48	0	951	89.0	87.5	1.5
12:50 PM	90	67	123	9	13	30.07	49	0	949	89.1	87.9	1.2
12:45 PM	89	67	134	11	16	30.07	50	0	942	88.3	87.1	1.3
12:40 PM	89	68	136	13	18	30.07	51	0	937	87.9	86.3	1.7
12:35 PM	89	68	139	11	15	30.07	52	0	930	87.7	86.4	1.3
12:30 PM	88	68	137	10	14	30.07	52	0	924	87.5	86.2	1.3
12:25 PM	88	68	104	10	13	30.07	52	0	918	87.0	85.6	1.5
12:20 PM	88	69	133	9	14	30.07	54	0	912	87.2	85.6	1.6
12:15 PM	88	68	142	11	14	30.07	54	0	890	86.5	85.0	1.5
12:10 PM	87	68	141	12	16	30.07	55	0	865	86.0	84.6	1.4
12:05 PM	87	68	123	11	16	30.07	56	0	890	85.7	84.4	1.3
12:00 PM	87	69	140	11	16	30.07	57	0	884	85.9	84.6	1.3
11:55 AM	86	69	141	11	14	30.07	58	0	871	85.2	83.9	1.3
11:50 AM	86	69	141	11	18	30.07	57	0	861	85.4	83.8	1.6
11:45 AM	86	69	121	9	13	30.07	59	0	853	84.9	83.6	1.4
11:40 AM	86	69	127	10	15	30.07	59	0	839	84.6	83.1	1.5
11:35 AM	85	69	128	10	14	30.07	59	0	830	84.5	83.1	1.4
11:30 AM	85	69	118	11	15	30.07	59	0	823	84.5	83.0	1.5
11:25 AM	85	69	102	9	13	30.06	60	0	813	84.4	83.1	1.3
11:20 AM	85	69	121	9	11	30.06	61	0	802	83.8	82.6	1.2
11:15 AM	84	69	141	10	14	30.06	62	0	790	83.1	81.9	1.2
11:10 AM	84	69	135	10	14	30.06	63	0	776	83.0	81.7	1.3
11:05 AM	84	69	112	9	13	30.06	63	0	767	83.1	81.8	1.3
11:00 AM	84	69	115	9	13	30.06	64	0	754	82.5	81.1	1.4
10:55 AM	84	70	118	9	13	30.06	65	0	741	82.4	81.1	1.3
10:50 AM	83	70	127	8	12	30.06	67	0	726	82.4	81.2	1.2
10:45 AM	83	70	110	7	11	30.06	67	0	713	81.5	80.2	1.4
10:40 AM	82	70	133	8	12	30.06	67	0	700	81.4	80.0	1.4
10:35 AM	82	70	123	8	11	30.06	68	0	687	81.1	79.8	1.4
10:30 AM	82	69	129	8	12	30.05	68	0	674	80.8	79.3	1.5
10:25 AM	82	69	133	10	12	30.05	68	0	658	80.5	79.1	1.4
10:20 AM	81	69	115	9	12	30.05	69	0	643	80.4	79.3	1.1
10:15 AM	81	70	114	7	12	30.05	70	0	628	80.4	79.3	1.1

10:10 AM	81	69	110	9	12	30.05	71	0	616	79.6	78.5	1.1
10:05 AM	80	69	115	9	13	30.05	71	0	600	79.5	78.2	1.3
10:00 AM	80	69	120	9	13	30.05	72	0	580	79.1	78.1	1.0
09:55 AM	80	69	117	10	13	30.05	72	0	566	78.9	77.7	1.2
09:50 AM	80	69	133	9	12	30.05	73	0	549	78.7	77.4	1.2
09:45 AM	79	69	126	10	13	30.05	73	0	531	78.7	77.5	1.2
09:40 AM	79	69	125	9	14	30.05	75	0	515	78.1	77.1	1.0
09:35 AM	78	69	116	11	15	30.05	76	0	497	77.5	76.6	0.9
09:30 AM	78	69	108	11	15	30.05	76	0	482	77.4	76.6	0.8
09:25 AM	78	69	110	9	13	30.05	76	0	465	77.4	76.7	0.7
09:20 AM	78	69	107	10	15	30.05	76	0	448	77.1	76.3	0.8
09:15 AM	78	69	127	10	13	30.05	76	0	431	77.0	76.1	0.9
09:10 AM	77	69	126	8	13	30.04	78	0	414	76.7	75.8	0.9
09:05 AM	77	69	128	9	13	30.04	78	0	399	76.5	75.6	0.9
09:00 AM	77	69	129	9	13	30.04	79	0	381	76.3	75.4	0.9

Data are a series of observations taken every 5 minutes at this West Texas Mesonet Site...

96.8 F - Maximum Temperature occurred at 04:25 PM
62.1 F - Minimum Temperature occurred at 07:00 AM
27.9 mph - Highest Wind Gust occurred at 11:25 PM
97.0 % - Maximum Rel. Humidity occurred at 07:20 AM
29.0 % - Minimum Rel. Humidity occurred at 02:55 PM
70.1 F - Maximum Dew Point Temp occurred at 10:50 AM
51.8 F - Minimum Dew Point Temp occurred at 11:45 PM

Notes: Delta T 2m-9m is the difference in temperature between the bottom and top of the tower (2meters and 9meters). Negative values of DeltaT indicate an inversion. RedFlag - indicates times with the average wind speed is > 25mph and RH < 15% at the same time. Critical Fire Danger.

Lubbock 3WNW-TTU Data from 06/20/2007

Max/Min = 89.1/62.4 F Max Wind = 34.6 mph @ 02:30 AM Total rain = 0.49 inches
Maximum Sustained Wind = 26.5 mph / 087 deg @ 02:30 AM
Maximum Daytime High = 89.1 occurred at 04:55 PM

TIME (CDT)	TEMP RAIN? (F) 6ft	DEW POINT	---WIND------ DIR (MPH	SPD MPH)	GUST	ALTIMITER SETTING (INCHES)	RH %	RAIN (IN)	SOLAR RADIATION VALUE	Temp (F)	Temp (F)	Delta T 6.5ft 30ft 6.5-30ft (F)
04:00 PM	88	55	356	4	7	30.16	34	0	889	87.4	87.0	0.4
03:55 PM	88	54	317	2	4	30.16	32	0	902	87.0	86.8	0.1
03:50 PM	87	57	323	6	8	30.16	37	0	921	86.3	85.8	0.5
03:45 PM	87	56	356	6	10	30.16	35	0	932	86.2	86.0	0.2
03:40 PM	88	56	035	5	10	30.16	35	0	949	86.6	86.2	0.4
03:35 PM	87	58	024	3	4	30.17	38	0	947	86.5	86.1	0.5
03:30 PM	87	58	345	3	7	30.17	39	0	914	85.9	85.6	0.3
03:25 PM	87	58	013	4	6	30.17	39	0	933	85.5	85.3	0.2
03:20 PM	86	60	340	6	10	30.17	42	0	937	85.4	85.2	0.2
03:15 PM	86	60	333	3	7	30.17	43	0	893	85.1	85.0	0.1
03:10 PM	86	61	359	6	10	30.18	44	0	868	84.9	84.6	0.3
03:05 PM	86	60	335	4	8	30.18	43	0	934	85.2	84.9	0.2
03:00 PM	86	61	318	2	5	30.18	44	0	905	85.1	85.0	0.1
02:55 PM	86	60	015	5	8	30.18	43	0	849	85.0	84.6	0.4
02:50 PM	86	59	011	3	6	30.19	41	0	1042	85.0	84.6	0.5
02:45 PM	86	61	339	5	8	30.19	45	0	888	84.8	84.2	0.5
02:40 PM	86	62	003	3	5	30.20	46	0	933	84.7	84.3	0.4
02:35 PM	85	61	329	5	9	30.20	46	0	968	84.3	83.5	0.8
02:30 PM	85	64	290	4	7	30.20	50	0	985	84.6	83.6	1.0
02:25 PM	85	62	338	3	8	30.20	48	0	1004	83.9	83.0	0.8
02:20 PM	85	65	345	7	10	30.21	54	0	978	84.0	83.3	0.7
02:15 PM	84	64	011	4	7	30.21	52	0	1032	83.5	82.8	0.6
02:10 PM	84	63	345	4	7	30.21	51	0	1032	83.3	82.5	0.8
02:05 PM	84	63	317	5	10	30.21	51	0	1017	83.0	82.1	0.8
02:00 PM	84	64	325	4	11	30.21	54	0	1006	83.6	82.7	0.8
01:55 PM	83	64	301	3	8	30.22	54	0	1005	82.3	81.4	0.9

Data are a series of observations taken every 5 minutes at this West Texas Mesonet Site...

89.1 F - Maximum Temperature occurred at 04:55 PM
62.4 F - Minimum Temperature occurred at 03:00 AM
34.6 mph - Highest Wind Gust occurred at 02:30 AM
93.0 % - Maximum Rel. Humidity occurred at 01:30 AM
31.0 % - Minimum Rel. Humidity occurred at 04:15 PM
66.9 F - Maximum Dew Point Temp occurred at 07:30 PM
53.1 F - Minimum Dew Point Temp occurred at 04:10 PM

Notes: Delta T 2m-9m is the difference in temperature between the bottom and top of the tower (2meters and 9meters). Negative values of DeltaT indicate an inversion. RedFlag - indicates times with the average wind speed is > 25mph and RH < 15% at the same time. Critical Fire Danger.

Lubbock 3WNW-TTU Data from 06/21/2007

Max/Min = 89.3/63.4 F Max Wind = 24.9 mph @ 06:50 PM Total rain = 0.00 inches
Maximum Sustained Wind = 17.3 mph / 122 deg @ 05:55 PM
Maximum Daytime High = 89.3 occurred at 04:30 PM

TIME (CDT)	TEMP RAIN? (F) 6ft	DEW POINT	---WIND------ DIR (MPH	SPD MPH)	GUST	ALTIMITER SETTING (INCHES)	RH %	RAIN (IN)	SOLAR RADIATION VALUE	Temp (F)	Temp 6.5ft (F)	Delta T 30ft 6.5-30ft (F)
12:55 PM	82	64	198	10	15	30.12	56	0	967	81.5	80.2	1.3
12:50 PM	82	64	197	9	12	30.13	55	0	961	81.3	80.2	1.1
12:45 PM	82	63	188	10	14	30.13	54	0	961	81.0	80.1	0.9
12:40 PM	82	64	186	10	14	30.13	55	0	954	81.3	80.3	0.9
12:35 PM	82	63	183	9	13	30.13	55	0	942	81.1	80.1	1.0
12:30 PM	81	63	192	9	15	30.13	55	0	941	80.4	79.5	1.0
12:25 PM	82	64	181	11	16	30.13	56	0	938	80.4	79.3	1.1
12:20 PM	82	64	168	10	15	30.13	56	0	931	80.5	79.4	1.0
12:15 PM	81	64	175	9	14	30.14	58	0	902	80.5	79.3	1.2
12:10 PM	81	64	167	10	13	30.14	58	0	894	80.1	78.9	1.2
12:05 PM	81	65	172	9	14	30.14	60	0	914	80.2	79.1	1.1
12:00 PM	81	64	173	9	13	30.14	59	0	906	79.6	78.6	1.0
11:55 AM	80	65	175	11	14	30.14	60	0	897	79.4	78.5	1.0
11:50 AM	80	64	177	9	13	30.14	60	0	888	79.1	78.0	1.1
11:45 AM	80	64	188	11	17	30.14	60	0	883	79.4	78.3	1.1
11:40 AM	80	65	179	10	13	30.14	63	0	873	78.8	77.7	1.1
11:35 AM	79	65	201	10	13	30.14	63	0	864	78.3	77.2	1.1
11:30 AM	79	65	202	11	14	30.14	64	0	853	78.0	76.9	1.1
11:25 AM	79	65	182	10	14	30.14	63	0	837	78.2	77.2	1.0
11:20 AM	79	66	191	8	11	30.14	64	0	803	78.4	77.1	1.3
11:15 AM	79	66	188	10	15	30.14	65	0	801	78.0	76.8	1.2
11:10 AM	79	65	188	9	14	30.14	65	0	799	78.0	76.9	1.1
11:05 AM	79	65	188	9	14	30.14	64	0	786	77.9	76.9	1.0
11:00 AM	79	65	180	9	13	30.14	65	0	777	77.7	76.8	0.9

Data are a series of observations taken every 5 minutes at this West Texas Mesonet Site...
89.3 F - Maximum Temperature occurred at 04:30 PM
63.4 F - Minimum Temperature occurred at 04:50 AM

24.9 mph - Highest Wind Gust occurred at 06:50 PM
95.0 % - Maximum Rel. Humidity occurred at 05:10 AM
35.0 % - Minimum Rel. Humidity occurred at 04:10 PM
65.5 F - Maximum Dew Point Temp occurred at 11:20 AM
57.1 F - Minimum Dew Point Temp occurred at 04:10 PM

Notes: Delta T 2m-9m is the difference in temperature between the bottom and top of the tower (2meters and 9meters). Negative values of DeltaT indicate an inversion. RedFlag - indicates times with the average wind speed is > 25mph and RH < 15% at the same time. Critical Fire Danger.

Lubbock 3WNW-TTU Data from 06/25/2007

Max/Min = 89.9/64.2 F Max Wind = 26.2 mph @ 11:20 PM Total rain = 0.00 inches
Maximum Sustained Wind = 18.4 mph / 117 deg @ 10:00 PM
Maximum Daytime High = 89.9 occurred at 03:55 PM

TIME (CDT)	TEMP RAIN? (F) 6ft	DEW POINT	---WIND------ DIR (MPH	SPD MPH)	GUST	ALTIMITER SETTING (INCHES)	RH %	RAIN (IN)	SOLAR RADIATION VALUE	Temp 6.5ft (F)	Temp 30ft (F)	Delta T 6.5-30ft (F)
12:50 AM	70	66	137	10	17	30.07	89	0	0	70.1	70.8	-0.8
04:45 PM	88	60	152	9	14	29.99	40	0	699	86.7	86.1	0.6
04:40 PM	86	59	169	6	10	30.00	42	0	699	85.2	85.2	0.0
04:35 PM	85	59	162	6	11	30.00	42	0	281	84.6	84.7	-0.2
04:30 PM	86	60	144	9	12	30.00	43	0	272	84.7	84.7	0.1
04:25 PM	87	60	133	6	9	30.00	40	0	229	85.9	85.1	0.8
04:20 PM	88	60	125	8	11	30.00	39	0	775	87.5	86.2	1.3
04:15 PM	87	60	171	7	12	30.00	42	0	885	86.1	85.6	0.5
04:10 PM	85	59	164	5	8	30.00	41	0	241	84.5	84.5	0.0
04:05 PM	86	59	153	8	11	30.00	41	0	222	84.8	84.6	0.2
04:00 PM	88	59	132	7	9	30.00	38	0	280	86.4	85.4	1.0
03:55 PM	90	59	156	7	13	30.00	36	0	804	88.3	86.6	1.7
03:50 PM	90	58	201	3	7	30.00	36	0	970	88.8	87.2	1.5
03:45 PM	89	58	091	2	4	30.01	35	0	968	88.0	87.3	0.8
03:40 PM	88	57	178	3	9	30.01	36	0	949	86.9	85.8	1.1
03:35 PM	87	59	138	7	11	30.01	40	0	966	85.8	85.0	0.8
03:30 PM	88	59	140	11	16	30.01	39	0	537	86.1	84.8	1.2
03:25 PM	88	60	150	6	11	30.02	39	0	998	87.0	86.1	0.9
03:20 PM	88	60	129	4	10	30.02	39	0	839	86.9	85.7	1.2
03:15 PM	86	60	118	9	15	30.02	42	0	1022	85.6	84.6	1.0
03:10 PM	85	58	138	7	11	30.02	41	0	425	84.0	83.6	0.4
03:05 PM	87	60	144	8	11	30.03	40	0	230	85.4	84.3	1.1
03:00 PM	88	59	177	6	11	30.03	39	0	974	86.6	84.6	2.0
02:55 PM	88	61	149	8	13	30.03	40	0	1055	87.2	85.3	1.9
02:50 PM	88	61	148	5	12	30.03	41	0	1028	86.3	85.1	1.2
02:45 PM	87	60	169	5	11	30.03	40	0	1072	86.2	84.5	1.7
02:40 PM	87	61	167	9	12	30.03	42	0	1045	85.8	83.9	2.0
02:35 PM	86	61	199	6	12	30.03	44	0	1043	85.4	83.8	1.5

02:30 PM	84	62	192	8	12	30.03	48	0	1053	83.7	82.7	1.0
02:25 PM	84	62	160	10	25	30.04	49	0	340	82.9	82.1	0.8
02:20 PM	85	62	132	8	14	30.04	47	0	895	84.3	83.3	1.1
02:15 PM	85	61	153	9	12	30.04	45	0	556	83.9	82.4	1.5
02:10 PM	86	62	152	8	15	30.04	47	0	906	84.5	83.2	1.2
02:05 PM	86	62	125	5	10	30.04	46	0	976	84.6	82.9	1.7
02:00 PM	85	62	141	9	15	30.04	47	0	1042	84.2	82.3	1.9
01:55 PM	86	62	148	10	15	30.04	46	0	1036	84.3	82.6	1.7
01:50 PM	85	63	150	8	16	30.04	48	0	1027	84.2	82.6	1.6
01:45 PM	85	63	152	9	16	30.05	48	0	1028	83.8	82.2	1.5
01:40 PM	85	62	125	9	13	30.05	48	0	946	84.0	82.7	1.3
01:35 PM	84	62	129	10	14	30.05	48	0	1022	83.6	82.2	1.4
01:30 PM	85	63	128	9	13	30.05	49	0	1008	83.8	82.0	1.7
01:25 PM	84	63	146	9	12	30.05	50	0	1003	83.4	81.7	1.7
01:20 PM	84	63	167	9	13	30.06	51	0	957	83.1	81.4	1.8
01:15 PM	83	64	176	9	14	30.06	53	0	764	82.1	80.9	1.2
01:10 PM	85	63	156	6	10	30.06	49	0	852	83.5	81.8	1.7
01:05 PM	84	64	129	6	11	30.06	52	0	1056	83.3	81.6	1.7
01:00 PM	83	64	144	9	14	30.06	54	0	1062	82.1	80.6	1.5

Data are a series of observations taken every 5 minutes at this West Texas Mesonet Site...

89.9 F - Maximum Temperature occurred at 03:55 PM
64.2 F - Minimum Temperature occurred at 06:35 AM
26.2 mph - Highest Wind Gust occurred at 11:20 PM
96.0 % - Maximum Rel. Humidity occurred at 07:10 AM
35.0 % - Minimum Rel. Humidity occurred at 03:45 PM
67.8 F - Maximum Dew Point Temp occurred at 11:30 PM
56.9 F - Minimum Dew Point Temp occurred at 03:40 PM

Notes: Delta T 2m-9m is the difference in temperature between the bottom and top of the tower (2meters and 9meters). Negative values of DeltaT indicate an inversion. RedFlag - indicates times with the average wind speed is > 25mph and RH < 15% at the same time. Critical Fire Danger.

Appendix I: Weather Conditions During Burning Plants in New Mexico

Weather conditions during each controlled plot burn at the TX-HILL study site in Eddy Co. and the NA, SA, and WA study sites in Lincoln Co., NM.

Site	Date	Time		Temperature (°C)		Relative Humidity (%)		Wind Average Speed (mph)		Wind Gust (mph)		Direction
		Start	Finish	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	
NA	4/6/2005	10:49	13:03	12	15	22	28	6	11	16	20	N – WNW
SA	3/12/2005	14:57	16:36	18	18	14	16	11	19	24	30	WSW – WNW
WA	3/3/2005	10:24	12:20	10	12	33	35	15	24	19	28	SW – SSW
WA	3/12/2005	10:15	14:15	16	19	12	17	14	27	25	35	W – WNW
TX-HILL	4/19/2004	11:51	12:41	23	26	45	55	0	5	.	.	Variable
TX-HILL	6/15/2004	11:30	12:48	32	37	16	33	8	12	.	18	E – ESE

Appendix J: USFWS Five-Year Review of Kuenzler's Cactus (selected pages)

U.S. FISH AND WILDLIFE SERVICE
SIGNATURE PAGE FOR 5-YEAR REVIEW DETERMINATION

KUENZLER'S HEDGEHOG CACTUS

CURRENT CLASSIFICATION __Endangered__

5-YEAR REVIEW DETERMINATION _____ Delist __X__ Endangered to Threatened

_____ Threatened to Endangered ____ No Change

APPROPRIATE LISTING/RECLASSIFICATION NUMBER ____4____

REVIEW CONDUCTED BY Region 2 Regional Office and NM Ecological Services Field Office__

Lead Field Supervisor, U.S. Fish and Wildlife Service

Approve Susan MacMullin Date 5/23/05

Do Not Approve _____ Date _____

Lead Regional Director, U.S. Fish and Wildlife Service

Concur Larry Shell acting Date 6/7/05

Not Concur _____ Date _____

U.S. FISH & WILDLIFE SERVICE
5-YEAR REVIEW

KUENZLER'S HEDGEHOG CACTUS
***Echinocereus fendleri* Englemann var. *kuenzleri* (Castetter, Pierce & Schwerin) L. Benson**

METHODOLOGY USED TO COMPLETE THIS 5-YEAR REVIEW

This review was a team effort comprised of biologists from the U.S. Fish and Wildlife Service (FWS) Region 2 Regional Office, the New Mexico Ecological Services Field Office, the New Mexico State Forestry Division, and the University of New Mexico. Robert Sivinski, Botanist for the New Mexico State Forestry Division, was contracted through a Section 6 grant to gather the relevant information and prepare a draft of the review. The preliminary draft was reviewed by Phil Tonne, University of New Mexico Natural Heritage program, for scientific accuracy. The FWS team then met with the contractor to discuss the draft and formulate a recommendation. The final review was prepared by a FWS Regional recovery biologist.

FR Notice:	Vol. 66, No. 139; Wednesday, July 21, 2004; 43621-43622
Lead Region:	Region 2, Southwest Contact: Stuart Leon, Chief Threatened and Endangered Species 505-248-6920
Lead Field Office:	New Mexico Ecological Services Field Office Contact: Lyle Lewis, Endangered Species Branch Chief 505-761-4714
Names of Reviewers:	Wendy Brown, Recovery Coordinator, FWS-Region 2 RO 505-248-6664
	Julie McIntyre, SCEP Biologist, FWS-Region 2 RO 505-248-6507
	Tracy Scheffler, Recovery Biologist, FWS-Region 2 RO 505-248-6665
	Steve Chambers, Senior Scientist, FWS-Region 2 RO 505-248-6658
	Susan Jacobsen, Listing Coordinator, FWS-Region 2 RO 505-248-6641
	Melissa Kreutzian, Wildlife Biologist, NM Ecological Services Field Office (505)346-2525 ex. 4728

REVIEW ANALYSIS

8. Application of the 1996 Distinct Population Segment (DPS) Policy to DPS-listings made prior to the enactment of the policy.

Not Applicable.

9. New Information: Improved Analysis

Geographic Information Systems (GIS) that provide mapping layers for geology, soils, vegetation, and elevation have been useful for identifying focus areas of potential habitats for field surveys (Chauvin et al. 2001). This has led to the identification of additional populations, and provided a basis for gross estimates of populations in unsurveyed areas.

10. New Information: Biology and Habitat

10.A. Is there relevant new information regarding the species' abundance, population trends, demographic features, or demographic trends?

Yes. Kuenzler's hedgehog cactus is more abundant and its range is more widespread than known when listed as endangered in 1979. DeBruin (1993) and Chauvin et al. (1998) documented 1,611 sightings of individual cacti on federal lands on the east-slope of the Sacramento Mountains. Additional populations in highway rights-of-way have been found on the west slopes of the Sacramento Mountains near Carrizozo for an additional 98 cacti (Bleakly 2001, Knight 1999). Sivinski (1996) observed 68 cacti on Lincoln National Forest in the Guadalupe Mountains and an additional 100 in 1999 (Sivinski 1999). Guadalupe Mountains surveys of BLM jurisdictions found 191 cacti (Ladyman et al. 1998, Chauvin et al. 2001). Subsequent surveys in 1998, 2001 and 2002 by USDA-Forest Service contractors counted 365 new cacti in previously unsurveyed areas (USDA-Forest Service 1998, 2001, 2002). Dr. David Wester found 594 previously undocumented cacti on BLM lands in the Fort Stanton area in 2003, another 231 cacti in 2004, and an additional 18 on BLM land in the Guadalupe Mountains (USDI-BLM 2003, 2004). In total, botanists have found at least 3,276 Kuenzler's hedgehog cacti during inventories from 1978-2004 of federal lands (and a few acres of private land near the type locality).

All surveyors for this cactus state that the numbers of sightings under-represent the current numbers of cacti present in the survey areas. DeBruin (1993) thought it reasonable to estimate that there are at least twice as many, or 3,000 plants, in all Sacramento Mountains survey areas, and possibly up to 4,500 plants. After a subsequent 2003 survey, Dr. David Wester estimated a total of 4,148 cacti in the Fort Stanton area alone (USF&WS Cons. #2-22-03-F-0078.2). Survey intensity affects the multiplier used for a reasonable estimate. For instance, Sivinski (1996) found 44 cacti (all adults) on a single ridge in the Guadalupe Mountains with two people randomly walking back and

Appendix K: Assistance Agreement between BLM and TTU

(Page 1).

Form 1511-1
(February 1989)

United States Department of the Interior
Bureau of Land Management

ASSISTANCE AGREEMENT

NOTE: By signing this document, the recipient accepts this agreement and agrees to perform in accordance with all the enclosed terms, conditions, and documents attached hereto.

1. AGREEMENT NO.
GDA030007

2. TASK ORDER NO.

3. TYPE OF AGREEMENT *(Check one)*
☐ GRANT ☐ CHALLENGE
☒ COOPERATIVE COST-SHARE

4. NAME, ADDRESS AND PHONE NO. OF ASSISTANCE OFFICER
Karen Dyckes y Montaño
Administrative Support Center
435 Montaño Road NE
Albuquerque, New Mexico 87107
(505) 761-8941

5. NAME, ADDRESS AND PHONE NO. OF RECIPIENT
Texas Tech University
203 Holden Hall
Lubbock, Texas 79409-1035
(806) 742-3884

6. NAME, ADDRESS AND PHONE NO. OF ASSISTANCE REPRESENTATIVE
Ty Bryson
Carlsbad Field Office
620 East Greene Street
Carlsbad, New Mexico 88220
(505) 234-5960

7. NAME, ADDRESS AND PHONE NO. OF RECIPIENT'S PROJECT MANAGER
David Wester
Texas Tech University
Department of Range, Wildlife and Fisheries Management
Lubbock, Texas 79409-2125
(806) 742-2841

8. PROGRAM STATUTORY AUTHORITY See basic agreement

9. STARTING DATE Upon Signature of AO

10. EFFECTIVE DATE Upon Signature of AO

11. COMPLETION DATE Septebmer 30, 2008

12. TYPE OF RECIPIENT *(Check one)*
☐ STATE
☐ LOCAL GOVERNMENT
☐ INDIAN TRIBAL GOVERNMENT
☒ EDUCATIONAL INSTITUTION
☐ INDIVIDUAL
☐ FOR-PROFIT ORGANIZATION
☐ NON-PROFIT ORGANIZATION
☐ OTHER (SPECIFY)

13. FUNDING INFORMATION

	Recipient	BLM
This obligation	$ -0-	$ -0-
Previous obligation	$ -0-	$ -0-
Total obligation	$ -0-	$ -0-
Share Ratio	0%	0%

14. ACCOUNTING AND APPROPRIATION DATA

CFDA NUMBER: 15.228

15. PROJECT TITLE AND BRIEF SUMMARY OF THE PURPOSE AND OBJECTIVES

The purpose of this agreement is to conduct coordinated planning, implementation, and studies with prescribed fire on the Kuenzler's hedgehog cactus, an endangered species, and its habitat.

16a. NAME AND TITLE OF SIGNER *(Type or print)*
Kathleen Harris
Associate Vice President for Research

17a. NAME AND TITLE OF ASSISTANCE ORDERING OFFICER *(Type or print)*
Karen Dyckes y Montaño
Grants and Agreements Specialist

16b. RECIPIENT
Karen Harris
(Authorized Signature)

16c. DATE SIGNED
7-11-03

17b. UNITED STATES OF AMERICA
BY Karen Dyckes y Montaño
(Signature of Assistance Officer)

17c. DATE SIGNED
7/16/03

Appendix L: Crosswalk of proposed and delivered products.

Appendix L. Crosswalk between proposed and delivered products.

Proposed	Delivered	Status
Information about fire effects on this species to government employees (BLM, USFWS)	Progress reports have been published in our Department's annual "Research Highlights" throughout the duration of this project. Results have been presented at an annual PI meeting hosted by JFSP. Results were presented to Dr. J. Nicholopoulos, Director, U.S. D.I., Fish and Wildlife Service, New Mexico Ecological Services Field Office, at an annual meeting in Lubbock.. Final report delivered to BLM in Carlsbad, NM. Our information has been recognized and used by USFWS in their "Five-Year" review of this species.	Done
Annual progress reports to JFSP		Done
MS thesis	May, B.C. 1996. Effects of fire on Kuenzler's hedgehog cactus. Unpubl. MS Thesis, Texas Tech University, Lubbock.	Done
Peer-reviewed publications		In progress
Results posted on Fire Ecology Center website (TTU)		In Progress