State of the Las Cienegas National Conservation Area. Part I. Condition and Trend of the Desert Grassland and Watershed

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EXECUTIVE SUMMARY

The Las Cienegas National Conservation Area (LCNCA) supports three of the rarest ecosystems in the American Southwest: riparian, aquatic, and semidesert grassland; is home to 6 endangered species; and has two proposed wild and scenic river segments. Its exceptional biological, cultural, and scenic values make it a local, regional, and national priority for the Bureau of Land Management (BLM) as well as for other public agencies and organizations.

In 2004, BLM entered into a cooperative agreement with The Nature Conservancy to evaluate the current status and condition of resources on LCNCA and to review its existing monitoring protocols. This is the first chapter of a comprehensive "State of the NCA" report, focusing on the LCNCA's grasslands and savannas. Future chapters, pending funding, will address the riparian and aquatic ecosystems, target species, and stresses on these systems and species. In this chapter, we analyze and interpret available inventory and monitoring data collected at 26 key areas since 1995 to determine the condition and trend of the upland watershed as well as stresses on the system including shrub encroachment, soil erosion, loss of perennial grass cover and exotic species expansion. Nine out of 25 key areas (36%) showed significant *directional* trends in substrate cover despite low statistical power. In addition, there were many significant changes in bare ground, litter, and live vegetation cover between 1995 and 2004. These changes represented improving conditions in 35% of key areas and declining conditions in 48% of key areas. A separate analysis of overall grassland condition using 10 condition indicators indicated that 66% of key areas were *moderately* or *greatly outside desired condition* due to low perennial grass cover, shrub encroachment, and an increased potential for soil erosion. However, 74% of key areas met RMP objectives for bare ground cover and/or the Similarity Index value in 2004 or the date of last measurement.

To place these results into an ecosystem management context, we developed a state-and-transition model for semidesert grassland that identifies important thresholds in vegetation composition between model states as well as management actions capable of moving vegetation from one state to another. Few key areas (33%) fell within Open Grassland, a vegetation state that historically predominated at LCNCA while more key areas (46%) have been encroached upon by shrubs but can be restored back to Open Grassland using prescribed fire or mechanical/herbicide treatments.

Differences between key areas in overall condition appeared to be unrelated to the amount of summer and annual precipitation received over the last 4 years and the frequency and intensity of livestock use. However, the mean number of condition indicators outside of their threshold values was significantly greater for key areas located in the 12-16" precipitation zone compared to those in the 16-20" precipitation zone. Despite the lower productivity of the former sites, there was no difference in the frequency and intensity of livestock use for key areas in the two precipitation zones. In addition, key areas with low perennial grass cover that did not meet the threshold value for this indicator were grazed more intensively between 1993 and 2004 (e.g., greater number of animal days for the 12-year period) and their annual grazing intensity when

grazed was higher compared to key areas that met the perennial grass threshold. However, key areas that did not meet the threshold also had significantly greater shrub cover than key areas that met it. An analysis of 2 pairs of side-by-side key areas, one fenced to exclude livestock and the other unfenced, showed that conditions were improving on the ungrazed key areas with decreases in bare ground cover and increases in perennial grass diversity and cover compared to the adjacent grazed areas.

Together these results suggest that some combination of climate (including drought stress), site-specific factors, and livestock grazing may be driving the pattern of grassland condition observed on LCNCA. However, given the small sample size of key areas, missing precipitation data, the lack of long-term precipitation records, problems with exclosure locations and the small number of exclosures, there is considerable uncertainty regarding which of these factors, either acting alone or in concert with others, is responsible for the current condition of grasslands. Increasing the total number of livestock exclosures adjacent to unfenced key areas (which BLM is implementing) as well as increasing the power of the monitoring protocol to detect change will assist in disentangling the effects of livestock grazing, climate, and site-specific factors on grassland condition. BLM's plans to initiate a prescribed burn program to reduce shrubs and increase perennial grass cover should improve grassland condition, while their efforts to evaluate stocking levels annually in the context of current grassland condition and the drought (through the TRT/RRT process) should also help. Together, the improved monitoring information will help refine management goals for upland watersheds and identify the appropriate management actions needed to achieve those goals, both of which will assist BLM in future adaptive management at LCNCA.

BLM, with input from the Las Cienegas Technical Review Team (TRT) and Range Resource Team (RRT), used the upland monitoring data collected in 2004 to make management decisions on the proposed grazing plan for the following winter and spring. In particular, their review of the monitoring data revealed concern over two pastures proposed for use due to low perennial grass cover. In response to this concern, the lessee revised his grazing plan, decreasing by 2 months, or 50%, the total amount of time that livestock spent in these pastures. Continued success of the adaptive management process for livestock grazing management will require that the field work, analysis and interpretation of monitoring data be completed over a short time period so that it is available for use by BLM, the TRT and other teams in their evaluation of annual grazing plans. A timeline was developed to facilitate the adaptive management process for grazing management decisions at LCNCA.

Finally, we evaluated the original upland monitoring protocol and found that the sampling effort was inadequate to detect a biologically-meaningful level of change in substrate cover variables over time. Based on a series of analyses, we proposed a revision of the monitoring protocol, building on the original one and increasing its ability to detect change and to evaluate management objectives in the Resource Management Plan (BLM 2003). We tested the revised protocol with BLM in the field in 2004. This revision resulted in no net increase in the annual monitoring effort on a per key area basis and only slightly increased the effort for 5- and 10-year interval monitoring, especially if one component of the original sampling protocol, pace frequency measurements, is de-emphasized.

ACKNOWLEDGMENTS

We would like to thank Rob Marshall, Andy Hubbard, Nina Chambers, Dan Robinett, Emilio Carrillo, Mac Donaldson and Karen Simms for generously sharing their insights, experience and knowledge with us throughout the project. Karen Simms, Grant Drennan, Keith Hughes and Steve Cohn valiantly dug through files and provided data that BLM had collected over the years. Mac Donaldson also generously shared his rainfall data, annual grazing histories, and information on past wildfires with us. Their continued willingness to answer our questions and share their perspectives greatly assisted us with the analyses presented in this report. Thanks also to Danielle O'Dell, Keith Hughes, Emilio Carrillo, the UA Range Club, Emily Brott, Amy McCoy, Nina Chambers and especially Mike and Kay Fagan for their help with the 2004 monitoring. Guy McPherson, Phil Heilman, Karen Simms, Dan Robinett, Emilio Carrillo, Keith Hughes, Andy Hubbard, Mac Donaldson and Phil Ogden generously agreed to review the manuscript and provided many thoughtful comments; the report has greatly benefited from their time and effort. Finally, we would like to thank the BLM, National Park Service, Sonoran Institute and The Nature Conservancy for their generous and continued financial support of the project.

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I. INTRODUCTION

1.1 THE SITE

The Las Cienegas National Conservation Area (LCNCA) encompasses 41,972 acres of Bureau of Land Management (BLM) public lands with inholdings of 5,225 acres of Arizona State Trust lands and 82 acres of private land. The surrounding Sonoita Valley Acquisition Planning District encompasses an additional 95,609 acres that are a mix of Bureau of Land Management (BLM), Arizona State Trust, and private lands. The LCNCA supports five of the rarest community types in the American Southwest: cienegas, cottonwood-willow riparian forest, sacaton grasslands, mesquite bosques, and semidesert grasslands. It is also home to 6 federally listed species, is on the National Register of Historic Places, and has two proposed wild and scenic river segments.

Its exceptional biological, cultural, and scenic values make it a local, regional, and national priority for the BLM as well as for other organizations and public agencies. On a national level the LCNCA has been chosen as a pilot project by the BLM for the 5-year funding and implementation strategy program that connects the Department of the Interior's (DOI) Strategic Plan to on-the-ground priority work identified in the LCNCA Resource Management Plan (RMP). Las Cienegas National Conservation Area also forms the northern anchor of an 800,000-acre conservation area identified in The Nature Conservancy's (TNC) Apache Highlands ecoregional assessment of conservation priorities (Marshall et al. 2004). In an analysis of 600 TNC conservation areas identified in the five ecoregions overlapping Arizona, the conservation area that includes LCNCA ranked highest in terms of biological uniqueness and irreplaceability.

Regionally and locally LCNCA has attracted much attention from organizations and public agencies interested in the protection of this unique resource. Pima County has identified LCNCA as a priority area in its Sonoran Desert Conservation Plan (SDCP) due to its native fish populations including the endangered Gila topminnow (Fromer 2004). The SDCP has been recognized as one of the nation's largest and most ambitious Habitat Conservation Plans (APA 2002). The National Park Service (NPS) and the Sonoran Institute have singled out LCNCA as an ideal proof of concept project for their Sonoran Desert Network Inventory and Monitoring Program. At the local level, the Sonoita Valley Planning Partnership (SVPP), a voluntary association of federal, state, and local agencies, organizations and private citizens who share a common interest in the resources and management of public lands within the Sonoita Valley, was instrumental in the designation of this landscape as a National Conservation Area. Secretary of the Interior Gail Norton acknowledged the importance of LCNCA and SVPP in a guest editorial in the Arizona Daily Star, saying *"Las Cienegas is extraordinary not only because of its scenic beauty and resources, but also because of the extraordinary local-federal partnership that led to its becoming a National Conservation Area under the Bureau of Land Management (Norton 2003)."*

1.2 Report Goals

Given the overwhelming interest in the protection and management of LCNCA's significant ecological and public values, BLM saw the need to evaluate the current status and condition of resources. To this end they entered into a cooperative agreement with TNC to compile and synthesize all pertinent available information for the three major ecological systems identified in the RMP: upland watershed (semidesert grassland and savanna), riparian (cienega wetland, riparian forest) and aquatic. The result of the compilation and synthesis is this *State of the LCNCA* report.

In this report, we take a systematic approach to each of the 3 ecosystems or habitats. First, we analyze, summarize and interpret all relevant inventory, monitoring and research data to determine current condition and trend of each habitat and whether RMP goals and objectives are being met. Second, we determine the status and trend of potential stresses and sources of stress for each of the habitats using available and new data. For the upland watershed, the following stresses were identified: shrub encroachment, soil erosion, loss of perennial grass species and cover, and exotic species expansion (Lehmann lovegrass). Third, we construct state-and-transition models for each of the 3 habitats. Thresholds in composition, structure and condition between model states are defined and natural disturbances and management actions that move the system from one state to another are identified. Fourth, we focus on target species for each of the habitats, analyzing available monitoring and research data to determine status and trend of populations both on the LCNCA and in southeastern Arizona. Upland targets include pronghorn and breeding and wintering sparrows. Finally, we conduct a quantitative review of existing BLM monitoring protocols, testing them against alternative protocols based on 3 criteria: how well they address and inform management goals and objectives; their statistical power to detect change; and their implementation costs (e.g, data collection, analysis, and presentation).

Using this approach, we have completed all work for the upland watershed at LCNCA (semidesert grassland and savanna) except for the analysis of population trends for target species. The following sections detail our results. We emphasize that our goal is to characterize current condition and trend (directional change) of the grassland-watershed over the 9-year period that monitoring data has been collected at LCNCA. A reviewer suggested that we analyze all cover and frequency data, comparing sequential years for changes in substrate cover and species density and/or dispersion, and interpret these comparisons using precipitation data collected at a single site and grazing records. This analysis has never been done, possibly because of the staggering number of statistical comparisons required and the low statistical power of the original monitoring protocol which exacerbates the inter-annual variability in the data. Although such an analysis would be useful in evaluating annual proposed grazing plans, it is beyond the scope of this report. Nevertheless, we have analyzed approximately half of the key area plot data in this manner and can complete the analysis in a separate report if future funding becomes available.

Another goal of this report (and of our cooperative agreement with BLM) is to make recommendations for revision of the upland monitoring protocol in order to facilitate adaptive management of the grassland-watershed. We modified the existing protocol by increasing the sampling effort for substrate cover (so that the protocol had adequate statistical power to detect biologically-meaningful change) and de-emphasizing the frequency sampling (see Appendices A, B). We focused on substrate cover because it relates more directly to watershed function and wildlife habitat and explicitly addresses RMP management objectives which frequency measurements do not (Appendix A). This is not to say that frequency sampling is not useful. However, since budgets and resources for monitoring are limited, we felt that increasing the statistical power of the protocol to detect change in substrate cover while de-emphasizing frequency sampling was preferable to sampling both under the existing protocol and having a low statistical power to detect change in either. Monitoring that informs adaptive management should have adequate replication, sufficient statistical power to detect biologically meaningful change, be directly tied to management objectives, and be practical to implement in the context of available resources (Elzinga et al. 1998).

The new protocol was field-tested with BLM in fall 2004 and the results are presented in this report. Ultimately, developing an ecosystem monitoring plan for LCNCA and implementing the monitoring necessary to facilitate a science-based adaptive management program is an important goal of the RMP and this project.

Following the model for the upland watershed, our plan is to complete all work for the riparian and aquatic systems as well as the population analyses for upland target species pending future funding. In addition, we will evaluate, revise if needed, and field-test monitoring protocols that address the management objectives for riparian and aquatic habitats as well as upland habitat for wintering and breeding sparrows. These results will be added to the report when completed.

LCNCA forms the northern anchor of a "proof of concept" area for cooperative ecosystem monitoring and is the initial focus for the Sonoran Desert Network (National Park Service) and other members of the Ecosystem Monitoring Partnership. (The Ecosystem Monitoring Partnership is a bi-national consortium of public and private entities, including BLM, interested in ecosystem monitoring for effective conservation and management of natural resources in the region.) Because LCNCA contains habitats and species common to other land management units in the region, monitoring approaches developed here will be applicable elsewhere in the region. Thus, National Park Service is supporting our effort at LCNCA as it complements the work of the Sonoran Desert Network (SDN) in other habitats. That is, we are developing statistically robust monitoring protocols that address monitoring parameters of mutual interest and we are assessing the applicability of these monitoring parameters and protocols to relevant vital signs identified by SDN and other members of the Partnership.

II. THE STATE OF UPLAND VEGETATION

2.1 INTRODUCTION

Of the five rare community types found at LCNCA, semidesert grassland is the most abundant, comprising roughly 94% of the total area. This grassland is part of a larger complex of semidesert grasslands within the Apache Highlands Ecoregion which includes central and southern Arizona, southern New Mexico and northern Mexico (Bailey 1995, 1998). Over the past 130 years grasslands in this borderland region have experienced dramatic changes including a reduction in perennial grass cover, shrub and tree encroachment, soil erosion, and fragmentation (Humphrey 1963, 1987; Buffington and Herbel 1965; Hastings and Turner 1965; Bahre 1991). The causes for these changes are debated, but experts have implicated regional climate change, suppression of wildfire, poorly-managed livestock grazing, and land cover conversion for agriculture and exurban development (Glendening 1952; Humphrey 1958; Hastings and Turner 1965; Cable 1967; Wright 1980; Bahre 1985, 1995; Swetnam 1990; Dick-Peddie 1993; Archer et al. 1995; McPherson 1995; Brown et al. 1997; McPherson and Weltzin 2000). The spatial extent of changes to borderland grasslands has recently been quantified (Gori and Enquist 2003). More than 36% of the historic grasslands in the region have been lost due to shrub encroachment. Of the remaining extant grasslands, 50% are shrub-encroached but restorable with fire while only 26% are open native grasslands (Gori and Enquist 2003). The grassland at LCNCA makes up a total of 4% of these open native grasslands.

Given the importance of LCNCA's grassland to the site and to the region and its ongoing public use, it is important to have a baseline understanding of its condition in order to manage it effectively. This section of the report analyzes past and current monitoring information to characterize the current status and trend of the grassland watershed at LCNCA.

Las Cienegas National Conservation Area contains portions of 4 active BLM allotments (Empire Cienega, Rose Tree, Vera Earl, and Empirita) as well as a research Area of Critical Environmental Concern (Appleton-Whittell ACEC; Figure 1). Since the vast majority of the available monitoring and inventory information has been collected on the Empire Cienega Allotment, both on and off LCNCA, the scope of our analysis and characterization of grassland condition and trend will be limited to this allotment.

2.2 METHODS

ECOLOGICAL SETTING

The grassland on the Empire Cienega Allotment occurs on 15 different ecological sites that span two precipitation zones (12 to16" and 16 to 20" of rainfall per year) across 74,146 acres (Figure 2). This translates into considerable variability in grassland composition and condition across the allotment. However, when looking at the allotment on a landscape scale, there are two distinct grassland types: the northern hills and the southern bottomlands (Figure 3). The northern hills, which fall mostly within the 12" to

Figure 1. Location of active BLM grazing allotments and the Appleton-Whittell Research Area of Critical Evironmental Concern within Las Cienegas National Conservation Area and its planning boundary.

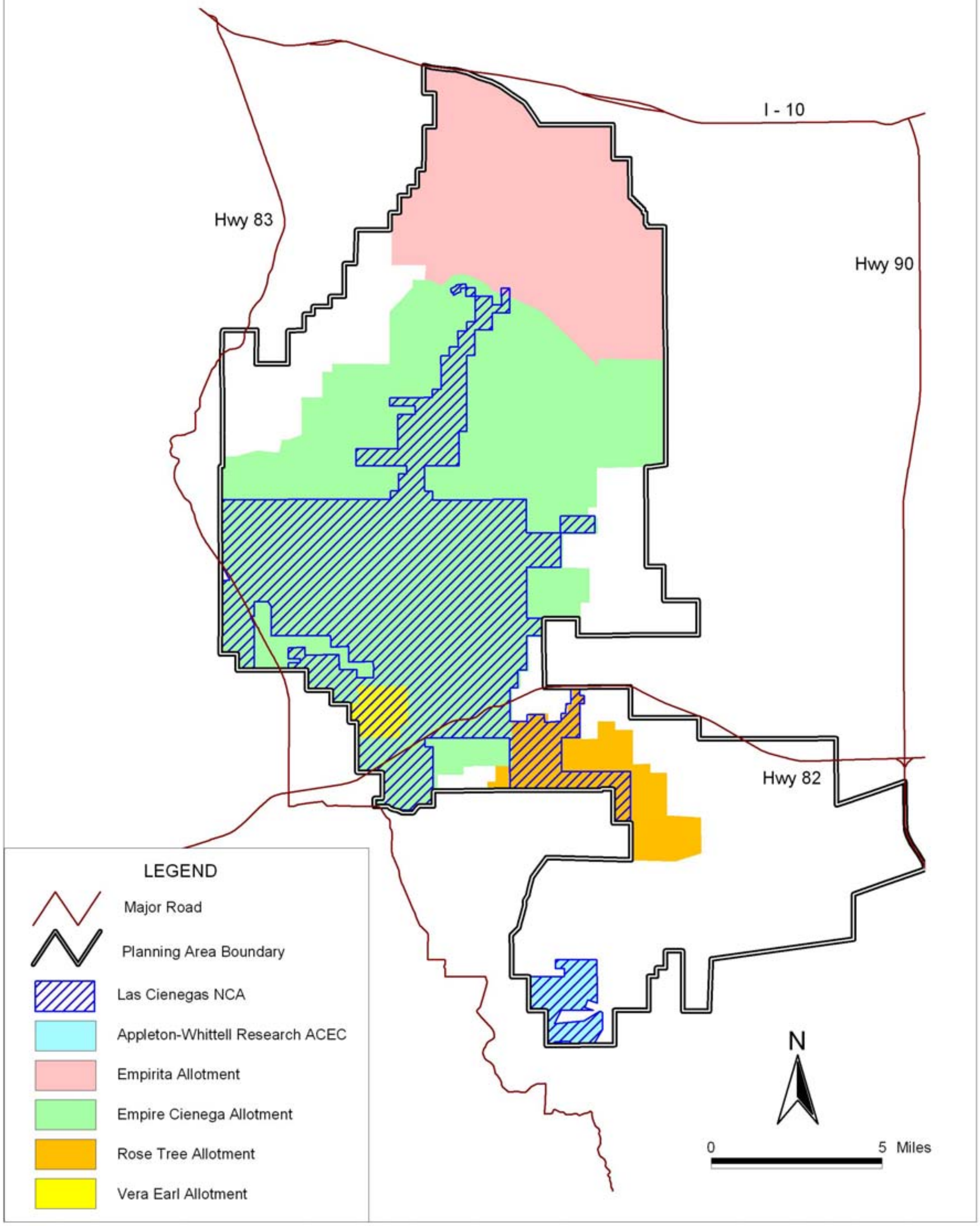


Figure 2. Location of NRCS ecological sites, spanning two precipitation zones (12-16 inches and 16-20 inches of rainfall per year), and 25 of 30 key area monitoring plots within the Empire Cienega Allotment.

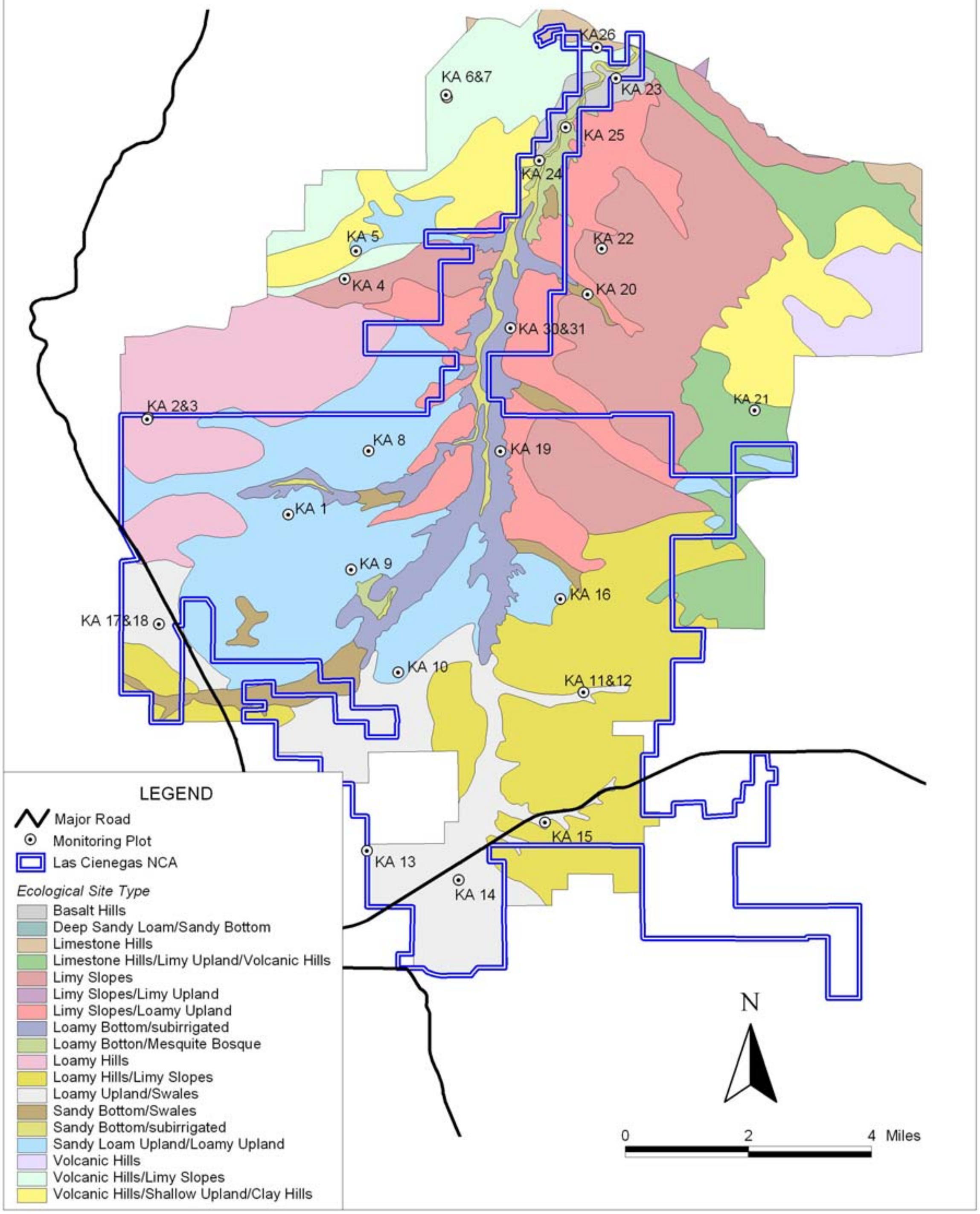
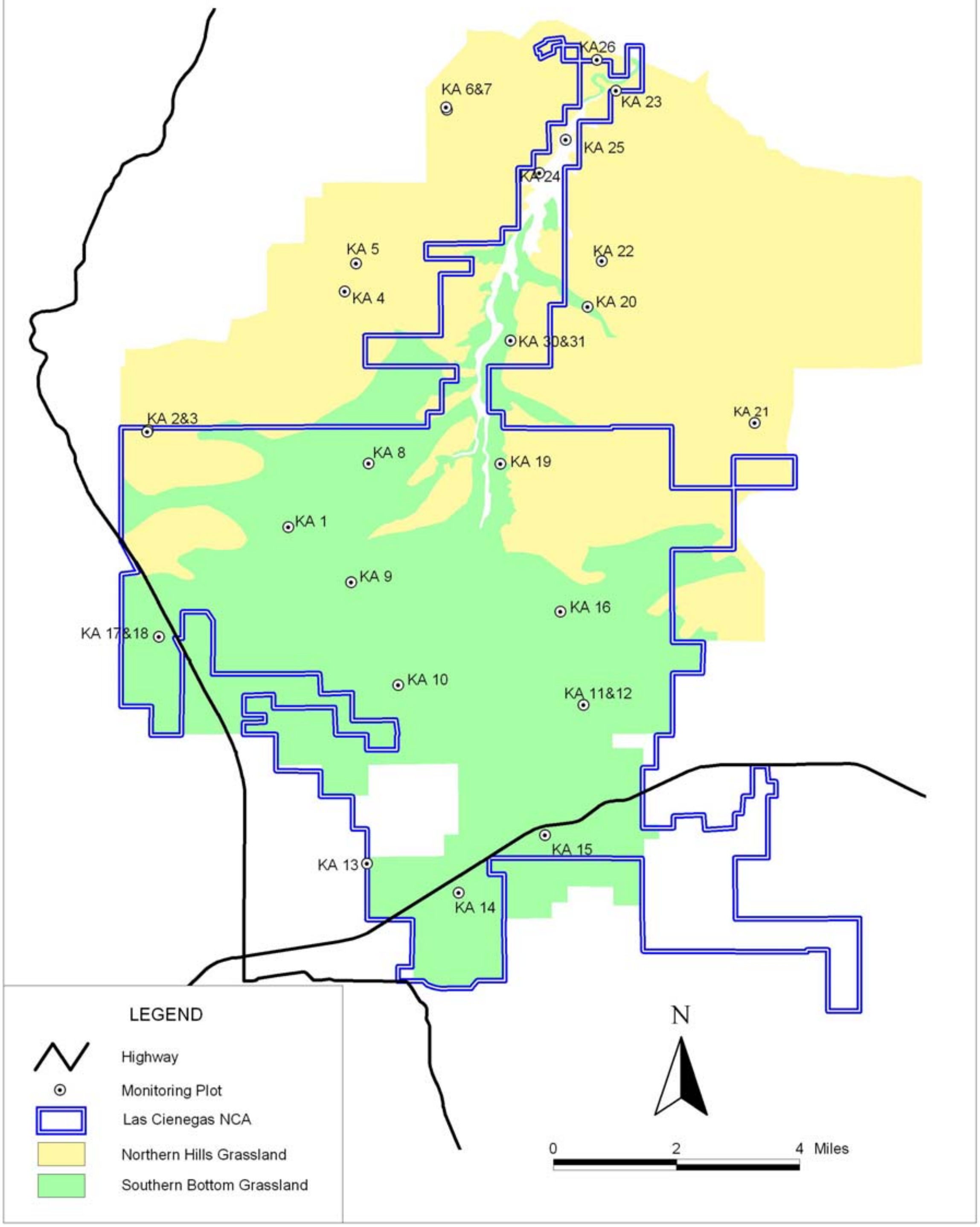


Figure 3. Location of the Northern Hill grassland, Southern Bottomland grassland and 25 of 30 key area monitoring plots within the Empire Cienega Allotment.



16" precipitation zone, have rocky soils and are potentially prone to losses in perennial grass cover and shrub encroachment. The southern bottomlands are split between the two precipitation zones, have loamy soils and are potentially prone to soil erosion (due to low plant and/or litter cover), exotic grass invasion, and tree (mesquite) encroachment.

DATA AVAILABILITY

Between 1995 and 2003 BLM and collaborators collected the following grassland monitoring information on 30 key area locations on the Empire Cienega Allotment: plant species' frequency, plant species' composition by weight, substrate cover and the NRCS's rangeland similarity index rating (Appendix A). These data were collected in 6 of the 9 years on 9 to 25 of the 30 key areas depending on the year (Table 1). In 2004, the grassland monitoring protocol was revised to increase its statistical power to detect change and the following information was collected on 23 of the 26 keys identified as sensitive to livestock grazing: substrate cover and perennial grass cover by species, shrub cover by species, and tree density (Appendix A). In addition, precipitation data were collected quarterly at a subset of these key areas (n = 18) between 2000 and 2004, and pasture use information has been recorded for most pastures from 1993 to 2004. Precipitation and pasture use information was provided by Mac Donaldson, the Empire Cienega Allotment lessee. In addition, a continuously recording rain gauge, established by the Agricultural Research Service (ARS) in 1988, is located in West Pasture. Based on the available information, this section will characterize (1) trends in grassland condition over the 9-year period; (2) current grassland condition; and (3) system stresses and their contribution to current condition. A goal of this characterization is to highlight areas within the Empire Cienega Allotment that are functioning properly as well as to identify at risk areas where changes in management may need to be considered. This information should assist in the management of the upland watershed at LCNCA and serve as a management guide for other semidesert grasslands in the region.

TRENDS AND CHANGES IN SUBSTRATE COVER

While there was a significant amount of monitoring data collected between 1995 and 2004, not all key areas were monitored regularly, not all measurements were made during a monitoring visit, and some of the data collected were of limited use in determining whether or not the more recently developed (2003) RMP management objectives were being met (Table 1; Appendix A). The most complete data set exists for substrate cover. We investigated trends in bare ground, live herbaceous vegetation, and litter cover for key areas over their period of measurement (in most cases 7 to 10 years depending on when they were established) using a linear regression analysis. Only key areas that were monitored 3 or more times were included in the analysis (Table 1). We also investigated the change in substrate cover variables over two time periods using a contingency table analysis; only key areas that were monitored 2 or more times were included in this analysis. The two time periods were: (1) between the first year of measurement and the last pre-2004 measurement, and (2) between the first year of measurement and 2004.

Table 1. Frequency of monitoring for 31 key areas in LCNCA between 1995 and 2004. Key areas in bold are those that are not suitable for evaluating livestock grazing effects because they are located too far from a water source. Light shaded boxes indicate years when substrate cover and/or frequency measurements were taken. Darker shaded boxes indicate years when dry weight rank and Similarity Index measurements were also made. The original monitoring protocol was used from 1995-2003, while the revised protocol was used in 2004.

Key Area	1995	1998	1999	2000	2001	2003	2004	No. Years Monitored
1	▓	░	▓				░	4
2	▓	░	▓	▓			░	5
3	▓	░	▓	▓			░	5
4	▓	░	▓			▓	░	5
5	▓	░	▓			▓	░	5
6	▓	░	▓			▓	░	5
7	▓	░	▓			▓	░	5
8	▓	░	▓	▓	▓		░	6
9a	▓	░	▓		▓			4
9b	▓	░	▓		▓		░	5
10	▓	░	▓		▓		░	5
11	▓	░	▓		▓		░	5
12	▓	░	▓		▓		░	5
13		░	▓		▓	▓	░	5
14		░	░		▓	▓	░	5
15		░	▓		▓	▓	░	5
16		░	▓	▓		▓	░	5
17	▓	░	░	▓			░	5
18	▓	░	░	▓			░	5
19	▓	░	▓			▓	░	5
20	▓		▓	▓				3
21	▓							1
22	▓		▓	▓			░	4
23	▓		▓				░	3
24	▓		▓					2
25	▓		▓					2
26	▓		▓					2
27	▓		▓					2
28	▓							1
30			░	▓	▓		░	4
31				▓	▓		░	3

GRASSLAND CONDITION INDICATORS

In an effort to get an overall sense of grassland condition, 10 grassland condition indicators were qualitatively evaluated for each key area. These indicators evaluated both long-term trends in the monitoring data as well as information collected in 2004 using the revised protocol. Condition indicators included: the percent of total perennial grasses that were trending down between 1995 and 2003, percent bare ground cover in 1995 and 2004, live basal vegetation cover in 1995 and basal perennial grass cover in 2004, similarity index values in 1995 and in the most recent year measured (this varies for each key area), total shrub cover in 2004, and total mesquite cover in 2004 (Table 2). All but one of the condition indicators were derived directly from the monitoring data (Appendix A, B). The one exception was the percent of perennial grasses trending down. To calculate this value, we determined the total number of perennial grass species in the key area from the frequency data and the percent of these species that showed a 10% or greater drop in frequency from the first year of measurement to 2003. This analysis did not include *Aristida* species as they were not uniformly identified to species from one year to the next.

These condition indicators were derived from a variety of sources. The percent bare ground cover and the similarity index value come from the management objectives articulated in the RMP for the grassland-watershed. Basal cover of perennial grasses is identified and used in some of the USDA Natural Resource Conservation Service (NRCS) ecological site descriptions as an indicator of range condition and live basal vegetation cover is comprised almost entirely of perennial grasses at LCNCA. The proportion of perennial grasses that are trending down is calculated from pace frequency data collected at LCNCA and may reflect a change in species' abundances (and composition) over time if decreases in frequency values for species are not solely related to changes in their distribution or dispersion. Finally, shrub and mesquite cover derive from a state-and-transition model developed later in this chapter and define grassland, shrub-steppe, and shrubland states. The relative abundance of these states changes with the occurrence and frequency of fire, an important natural process that historically maintained grasslands and grassland species (Humphrey 1958; McPherson 1995). In addition, as shrubs increase they begin to compete with perennial grasses for water and nutrients and autogenically modify sites through the alteration of soils and microclimate, eventually resulting in a reduction of perennial grasses or their failure to re-colonize or increase at sites following drought (Martin and Cable 1962; Archer et al. 1988; McPherson 1997). As shrubs increase and semidesert grasslands are converted to shrub-dominated communities, infiltration is reduced while water runoff and erosion rates are increased (Schlesinger et al. 1990); for this reason plant community composition and distribution relative to infiltration and runoff is one of 17 indicators of rangeland health identified by NRCS and ARS (Pellant et al. 2000).

Together the condition indicators provide a synthetic evaluation of grassland condition as they evaluate hydrologic function and soil stability through bare ground and live basal vegetation cover measurements, species composition through perennial grass trends and similarity index values, and proper functioning fire regimes through shrub and mesquite cover values. These indicators were chosen for four reasons. First, they are based on information that was available from the monitoring data. Second, they are vital to BLM's evaluation of their success in reaching management objectives for the NCA and they address Standards 1 and 3 of the Arizona Standards for Rangeland Health. Third, they provide a characterization of grassland condition that considers the entire ecosystem and historic natural processes which is consistent with the approach that NRCS is using in their revision of the ecological site descriptions including the development of state-and-transition models (D. Robinett, pers. comm.). Finally, they are key indicators of stresses on grasslands such as drought, livestock grazing, and fire suppression.

Table 2. Analysis of 10 grassland condition indicators for 23 key areas identified as appropriate for evaluating livestock grazing effects. Values identified as outside of the threshold for each condition indicator are highlighted in grey (see Table 3). Overall grassland condition is highlighted in the final column as the total number of indicators *outside desired condition*. Dark grey denotes key areas *greatly outside desired condition*, light grey denotes areas *moderately outside desired condition*, and white denotes areas *within to slightly outside desired condition*.

Key Area	Ecological site	Perennial Grass Species Trending Down (%)	Shrub Cover (%)	Mesquite Cover (%)	Shrubland Conversion?	Meeting Bare Ground Objective? 1995	Meeting Bare Ground Objective? 2004	Live Basal Vegetation Cover 1995 (%)	Perennial Grass Basal Cover 2004 (%)	Similarity Index 1995	Similarity Index , last measure	Total Indicators Outside Thresholds
1	Loamy upland	31	10.6	5.2	No	No	No	11	9.5	54.5	58	3
2	Loamy hills	10	22	4.7	No	Yes	Yes	9	12.7	92	92.6	1
3	Loamy hills	40	23.6	2.7	No	Yes	Yes	14	7.5	71.5	65.7	1
4	Limy slopes	25	28.8	0	No	Yes	Yes	7	4.2	60	69	3
5	Shallow upland	40	36.1	2.1	Yes	Yes	Yes	7	2.8	65.5	67	4
6	Limy slopes	17	27.7	0.5	No	Yes	Yes	10	4	85	79	2
7	Volcanic hills	43	27.4	1.3	No	Yes	Yes	9	3.8	71.5	78	3
8	Sandy loam upland	71	21.6	14.4	No	No	No	10	7.9	44	44.1	6
9	Sandy loam upland	29	22.7	16	No	No	No	10	10.5	32	18.7	7
10	Loamy bottom swales	33	10.9	10.3	No	No	Yes	11	26.8	54.5	72.2	2
11	Loamy hills	17	16.8	0	No	Yes	Yes	12	20.3	85	92.4	0
12	Loamy hills	29	8.3	0.4	No	Yes	Yes	11	11	59	53.8	1
13	Loamy upland	22	0.6	0	No	No	Yes	11	18.9	NA	71.7	2
14	Loamy bottom swales	17	4.2	0	No	Yes	Yes	23	29.6	NA	68.3	0
15	Limy slopes	0	6.6	0	No	Yes	Yes	11	22.5	NA	66.3	0
16	Loamy upland	33	6	1.9	No	No	Yes	12	20.4	NA	34	3
17	Loamy upland	33	6.6	5.4	No	Yes	No	12	12.4	63	46.3	3
18	Loamy upland	13	5.8	2.1	No	Yes	Yes	11	17.8	42	56.3	1
19	Loamy bottom subirrigated	0	4.3	4.3	No	Yes	Yes	28	19	65.5	84	0
22	Limy slopes	14	27.8	0.1	No	Yes	Yes	17	5.9	54	79.8	1
23	Basalt hills	33	36.4	4.6	Yes	Yes	Yes	11	1.7	70.5	63	4
30	Loamy upland	20	13.6	6.6	No	No	Yes	12	11.3	NA	51.63	2
31	Sandy loam upland	20	5.1	1.4	No	No	No	4	5.3	NA	44.8	5

THRESHOLDS FOR GRASSLAND CONDITION INDICATORS

For each indicator, we identified a threshold value outside or beyond which the integrity of the grassland-watershed was at risk from excessive soil erosion, loss of perennial grass cover and diversity, and altered hydrological function. These thresholds were determined from a variety of sources including the peer-reviewed literature, government agency reports and management plans, information obtained from various range management specialists, and our own professional judgment. The threshold values and sources for their identification are summarized in Table 3.

As indicated above, BLM has asked us as part of our cooperative agreement to develop a monitoring plan that can detect changes in grassland condition "before critical thresholds are crossed and permanent damage to the system occurs". The above indicators measure important components of grassland condition as well as stresses on grasslands and the identified thresholds can serve to alert or trigger a change in management by the BLM before permanent damage occurs.

Table 3. Thresholds for 10 grassland condition indicators and the sources for these values. Values outside the indicated thresholds are considered undesirable because they fail to meet RMP objectives or they are indicative of a range site in poor or declining condition or at risk of type conversion to shrubland. See text for further explanation

Condition Indicator	Threshold	Information Source
Bare ground cover (%), 1995 Bare ground cover (%), 2004	Should not exceed 30%	LCNCA Resource Management Plan (BLM 2003)
ESI Similarity Index, 1995/date of last measurement	Should equal or exceed 50%	LCNCA Resource Management Plan (BLM 2003)
Live vegetation basal cover (%), 1995 Perennial grass basal cover (%), 2004	Should exceed 5%	NRCS Ecological Site Descriptions for limy slope, loamy bottom subirrigated and loamy upland, indicative of site in fair, good or excellent condition; Hennessey et al. 1983; P. Warren, TNC, unpublished data from Malpai Borderlands Group
Shrub canopy cover (%), Mesquite canopy cover (%)	Should not exceed 20% for all shrubs, or 15% for mesquite	D. Robinett, NRCS, personal communication; Indicator of rangeland health: plant community composition and distribution relative to infiltration and runoff (Shaver et al. 2000).
Type conversion to shrubland	Should not exceed 35% canopy cover for all shrubs or 20% canopy cover, mesquite	McAuliffe 1995; McPherson 1997; D. Robinett, NRCS, personal communication; Indicator of rangeland health: plant community composition and distribution relative to infiltration and runoff (Shaver et al. 2000).
Percentage of perennial grass species trending down in abundance, 1995-2003	Should not exceed 20%	Professional judgment of the authors

One key condition indicator that was intentionally left out of the above analysis was the presence of Lehmann lovegrass. We did this so as to not overly weight the abundance of this species in the overall condition analysis. Currently, the percent perennial grass species trending down as well as the similarity index ratings get at the potential negative impacts of Lehmann lovegrass on grassland condition. However, given the importance of this species' invasion in the grassland community at LCNCA, a separate analysis of its spread, based on frequency data and its canopy cover in 2004, was completed for the 23 key areas that were monitored in 2004.

2.3 Results and Discussion

Trends and Changes in Substrate Cover

Nine out of 25 key areas (36%) showed significant increases or decreases in 1 or more of the cover variables over time (Table 4). The trends indicated declining conditions in 4 key areas (7, 17, 22, 23) related to increases in bare ground cover and decreases in litter and/or live vegetation cover, and improving conditions in 4 key areas (9B, 10, 11, 18), related to decreases in bare ground cover and increases in litter and/or live vegetation cover. Key Area 9B was established in a recently burned area in 1995 and litter and live herbaceous vegetation have subsequently increased (recovered) following the burn, while KA 18 was fenced and excluded from livestock grazing 25 years ago and bare ground cover has continued to decrease there over time. The remaining key area (14) showed no net change in condition with an increase in live vegetation cover balanced by a decrease in litter cover. All other key areas showed no significant directional change in cover variables between 1995 and 2004 (Table 4). However, it is important to note that cover values can typically vary from one measurement period to the next due to sampling error and variation in annual precipitation and grazing intensity. Detecting a statistically significant trend in the face of this variability is difficult, especially with a small number of sample points, i.e., most key areas were monitored only 4 to 5 times between 1995 and 2004. This underscores the need to monitor frequently (annually) and sample intensively so that there is sufficient statistical power to detect change between two monitoring periods.

Although 36% of key areas showed significant directional trends in substrate cover in the regression analysis, our analysis of change between two time periods showed many significant changes in substrate cover over time in the key areas (Table 5). We focus on the results for one time period, date of first measurement vs. 2004 because these results reflect current conditions at LCNCA and potentially the impact of a prolonged drought on the grassland community. Eighteen out of 23 key areas measured in 2004 (78%) showed significant changes in 1 or more cover variables from when they were first measured, in most cases in 1995 or 1998. These changes represent an improvement in 8 key areas, or 35% (9A, 10, 11, 13, 15, 16, 18, 19) and a decline in 11 key areas, or 48% (1, 2, 3, 7, 8, 14, 17, 22, 23, 30, 31). Some of these changes may be due to the fact that key areas were enlarged in 2004 to accommodate the new sampling design and thus the area monitored in 2004 was not precisely the same as in previous years. However, the monitoring transects were never permanent and this possibility would also apply to the pre-2004 monitoring, although probably to a lesser extent (Appendix A).

GRASSLAND CONDITION

Seventeen out of 23 key areas (74%) met RMP objectives for bare ground cover and the Similarity Index value when last measured (Table 2). However, the grassland condition analysis showed that 19 out of 23 key areas (83%) had 1 or more condition indicators outside of desired thresholds. To facilitate discussion, key areas were operationally grouped into one of three categories: *greatly outside desired condition* (with 4 to 7 indicators outside of threshold values); *moderately outside desired condition* (with 2 to 3 indicators outside of threshold values), and *within or slightly outside desired condition* (with 0 to 1 indicators outside of threshold values) [Table 2]. Our use of the term "desired" does not imply that all of the condition indicators and associated thresholds have been adopted as objectives for the area. However, as previously discussed, the indicators represent different components of grassland condition; values that exceed or are outside of the threshold values for these indicators indicate risk to the integrity of the grassland-watershed from excessive soil erosion, loss of perennial grass cover and diversity, and altered hydrological function. In this sense, meeting the threshold values for the condition indicators is a desirable condition.

Based on this grouping, 5 of 23 key areas (22%) were *greatly outside desired condition*, 10 key areas (44%) were *moderately outside desired condition*, and 8 key areas (34%) were *within or slightly outside desired condition* (Figure 4). Of these, 6 key areas (26%) did not meet RMP objectives and another 5 key areas (22%) failed to meet the threshold value for perennial grass basal cover.

A breakdown of key areas *greatly outside desired condition* shows key areas 8 and 9 with the greatest number of condition indicators outside of threshold values, 6 and 7 out of 10, respectively (Table 2; Figure 4). These areas had a high proportion of their perennial grasses trending downward, high levels of total shrub cover as well as high levels of mesquite cover. They also consistently failed to meet the bare ground and similarity index objectives articulated in the RMP. Key area 31 had 5 of 10 condition indicators outside of threshold values with a high proportion of perennial grasses trending downward, bare ground cover and similarity index values that failed to meet RMP objectives, and basal vegetation/perennial grass cover that was very close to the threshold value. All three of these key areas are located on sandy loam ecological sites and are experiencing Lehmann lovegrass invasion. Overall, these sites are at considerable risk of soil erosion (due to high bare ground cover) and type conversion to mesquite shrubland, and/or non-native grassland. Key areas 5 and 23 had 4 condition indicators outside of threshold values, with a high proportion of perennial grasses trending downward, very high shrub cover values, and low live basal cover of herbaceous vegetation including perennial grasses. These key areas are located on shallow upland and basaltic hill ecological sites, respectively, and while not prone to soil erosion, they are at considerable risk of type conversion from a grassland with scattered shrubs to shrubland, i.e., desert scrub.

Table 4. Results of a linear regression analysis of change in bare ground, live vegetation, and litter cover from the year of first measurement to 2004 for key areas on LCNCA. All key areas were subject to potential grazing effects. Regressions where no statistically significant change was observed are shaded in light gray, + represents a statistically significant increase in the cover variable over time, and – represents a decrease over time. Sample sizes for the different regressions varied from 3 to 5 years and only key areas with 3 or more years of sampling were included in the analysis. Key areas 9B and 20 were not measured in 2004 but were last measured in 2001 and 2000 respectively. Significance levels are indicated: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Key Area	1st Year Measure	Bare Ground Change?	Live Vegetation Change?	Litter Change?	Litter & Live Vegetation Change?
1	1995				
2	1995				
3	1995				
4	1995				
5	1995				
6	1995				
7	1995	+ *			
8	1995				
9A	1995				
9B	1995	– *			+ **
10	1995		+ **		
11	1995		+ *		
12	1995				
13	1998				
14	1998		+ *	– **	
15	1998				
16	1998				
17	1995	+ *		– **	– ***
18	1995	– *			
19	1995				
20	1995				
22	1995	+ *	– **		– *
23	1995				– **
30	1999				
31	2000				

Key areas 1, 3, 4, 6, 7, 10, 13, 16, 17, and 30 fell into the *moderately outside desired condition* category, the majority of these having a high proportion of perennial grasses trending downward and failing to meet bare ground objectives. Key areas 4, 6, and 7 exhibited low basal cover of herbaceous vegetation and perennial grasses while key areas 16 and 17 failed to meet the similarity index objective when they were last measured.

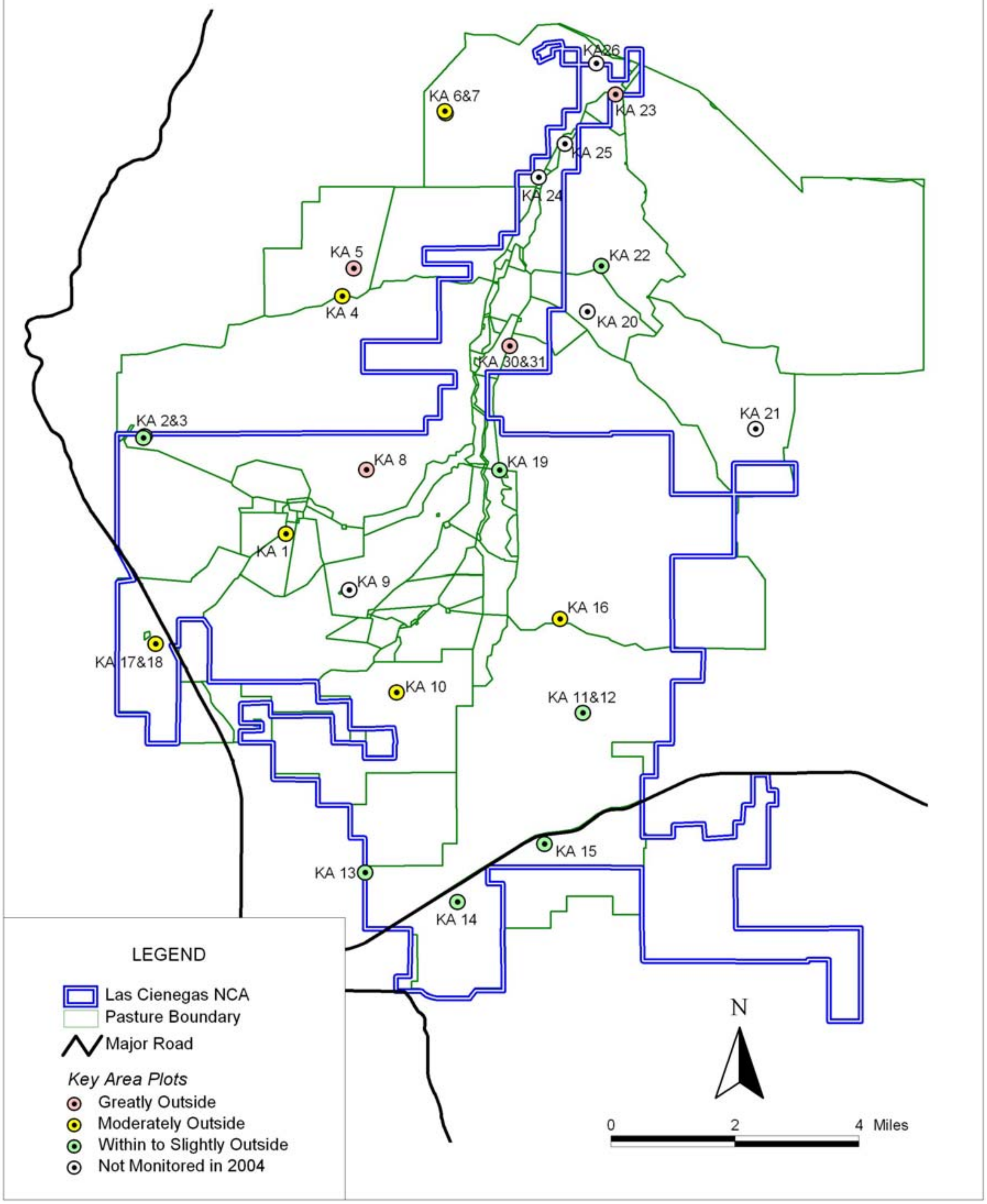
Key areas 2, 11, 12, 14, 15, 18, 19, and 22 were *within or slightly outside desired condition*. Key area 12 had a high proportion of perennial grasses trending down and key areas 2 and 22 had high levels of shrub cover; key area 22 also had low perennial grass cover, barely exceeding the threshold value of 5%. Key area 18 did not meet the similarity index rating in 1995 but did so in 2000 when it was last measured. The remaining 4 key areas (11, 14, 15, and 19) had no condition indicators outside of threshold values.

Table 5. Change in bare ground, live vegetation, litter, and litter cover between the date of first measurement (A), date of the last pre-2004 measurement (B), and 2004 (C) for key areas in LCNCA. Key areas that are not subject to potential grazing effects are indicated in bold. Comparisons where no statistically significant change was observed are shaded in light gray, those showing a significant increase in the cover variable are indicated by a +, and – represents a significant decrease in the cover variable over the indicated time period. The significance levels are also given: * p < 0.1, ** p < 0.05, *** p < 0.01. Some key areas were not measured in 2004 preventing comparisons with earlier years; these are indicated with diagonal lines.

Plot	1^{st} Year Measure (A)	Last Measure, pre-2004 (B)	Bare Ground Change? A vs. B	Bare Ground Change? A vs. C	Live Vegetation Change? A vs. B	Live Vegetation Change? A vs. C	Litter Change? A vs. B	Litter Change? A vs. C	Litter & Live Change? A vs. B	Litter & Live Change? A vs. C
1	1995	1999		+ ***				- **		- ***
2	1995	1999						- **		- *
3	1995	2000				- **				
4	1995	2003								
5	1995	2003	+ ***							
6	1995	2003			- *					
7	1995	2003	+ ***	+ ***	- *	- *	- ***	- *	- ***	- ***
8	1995	2003		+ *	+ *			- **		- **
9A	1995	2001			+ *		- **			+ *
9B	1995	2001	- ***		+ *		+ ***		+ ***	
10	1995	2001	- ***	- **	+ **	+ ***	+ *		+ ***	+ **
11	1995	2001				+ **			+ **	+ ***
12	1995	2001			+ ***		- *			
13	1998	2003	+ **	- ***						
14	1998	2003				+ ***	- *	- ***		- ***
15	1998	2003				+ *				+ ***
16	1998	2003		- **		+ *		- **		
17	1995	2000		+ ***	+ *		- **	- ***		- ***
18	1995	2000					- **		- ***	+ *
19	1995	2003	- **		- *	- *	+ **	+ *	+ **	
20	1995	2000					+ ***		+ ***	
22	1995	2000		+ ***		- ***		- ***	- **	- ***
23	1995	1999				- ***	- **	- ***		- ***
24	1995	1999								
25	1995	1999			- *		+ *			
26	1995	1999	- **							
27	1995	1999					- ***		- ***	
30	1999	2001	- **					- **		
31	2000	2001					- ***	- ***	- **	- ***

Given these results, a closer look at key areas and the areas that surround them is needed to assess whether management changes would improve grassland condition. Field visits by BLM, the lessee and various members of Las Cienegas Technical Review Team in 2004/2005 revealed that 8 of the 9 key areas evaluated were representative of the surrounding area. This is not surprising given the attention LCNCA has received by the range management community. However, to reduce uncertainty regarding the representativeness of key areas, the remainder should be evaluated in 2005 so that any changes in their placement can be made prior to the Fall 2005 monitoring season.

Figure 4. Location of key area monitoring plots that are greatly outside, moderately outside, or within or slightly outside desired condtions within the Empire Cienega Allotment. Key areas not monitored in 2004 and pastures boundaries are also shown.



State-and-Transition Model for Semidesert Grassland and LCNCA Key Areas

In order to put the results for grassland condition into an ecosystem context, a state-and-transition model for semidesert grasslands was developed (Figure 5). This model has a total of 10 possible vegetation states with 1-2 transitions into and out of each state. Of the 10 possible vegetation states, 5 represent states that have crossed an ecological threshold resulting in a type conversion; we refer to these as threshold states. Once a threshold state has been reached, ecological processes like fire or climate variability no longer function in moving vegetation between states and large energy (resource) inputs are needed to return to a non-threshold state. The 5 non-threshold states represent the natural range of variability in semidesert grassland vegetation where natural processes can still operate and historically set the proportionate abundance of these different states. There are two alternative paths moving to and from Open Grassland that are determined by ecological site. Loamy upland, sandy loam upland, loamy bottom swale, and loamy bottom sub-irrigated sites follow the Grass/Mesquite path, while other ecological sites follow the Grass/Mixed Shrub path. Loamy hill sites can follow either path depending on aspect and elevation. Among the non-threshold states, there are two states, Grass/Bare ground and Mixed Shrub/Grass, that occurred historically as a result of drought but usually returned to the adjacent state when average-precipitation resumed. Grazing rest is likely to facilitate this return. In cases of extreme drought, some proportion of this vegetation state presumably moved to Desert Scrub with continued soil erosion, but poorly managed livestock grazing has greatly increased the probability of this transition in the borderland region (Hennessey et al. 1983; McAuliffe 1995). The threshold values for shrub cover in the state-and-transition model come from a grassland assessment conducted by TNC, the published literature, as well as from information contained within the NRCS ecological site guides (Gori and Enquist 2003; Table 3). The values for perennial grass cover are conjectural and based on limited field data; these values are under review by BLM's Las Cienegas Technical Review Team (TRT).

All of the key areas identified as *greatly outside desired condition* fall into 3 of the 7 threshold states: Desert Scrub, Exotic Grassland, and Exotic Grass/Mesquite/Shrub (Figure 6). Key areas that were *moderately outside* or *within or slightly outside desired condition* fall into 4 non-threshold states: Open Grassland, Grass/Mesquite, Grass/Mixed Shrub, and Mixed Shrub/Grass grassland-steppe. Few key areas (8 out of 24, or 33%) are Open Grassland, a vegetation state that predominated historically. The remaining key areas in non-threshold states (11 out of 24, or 46%) have been encroached upon by shrubs including mesquite but may still be restored back to Open Grassland with fire or other vegetation treatments that reduce shrubs (Figure 5). The predominance of the latter key areas (46%) and the type conversion that has occurred on 2 out of 23 key areas (8%) points to an immediate need for prescribed fire or other vegetation treatments (mechanical, chemical) in areas experiencing problems with shrub encroachment.

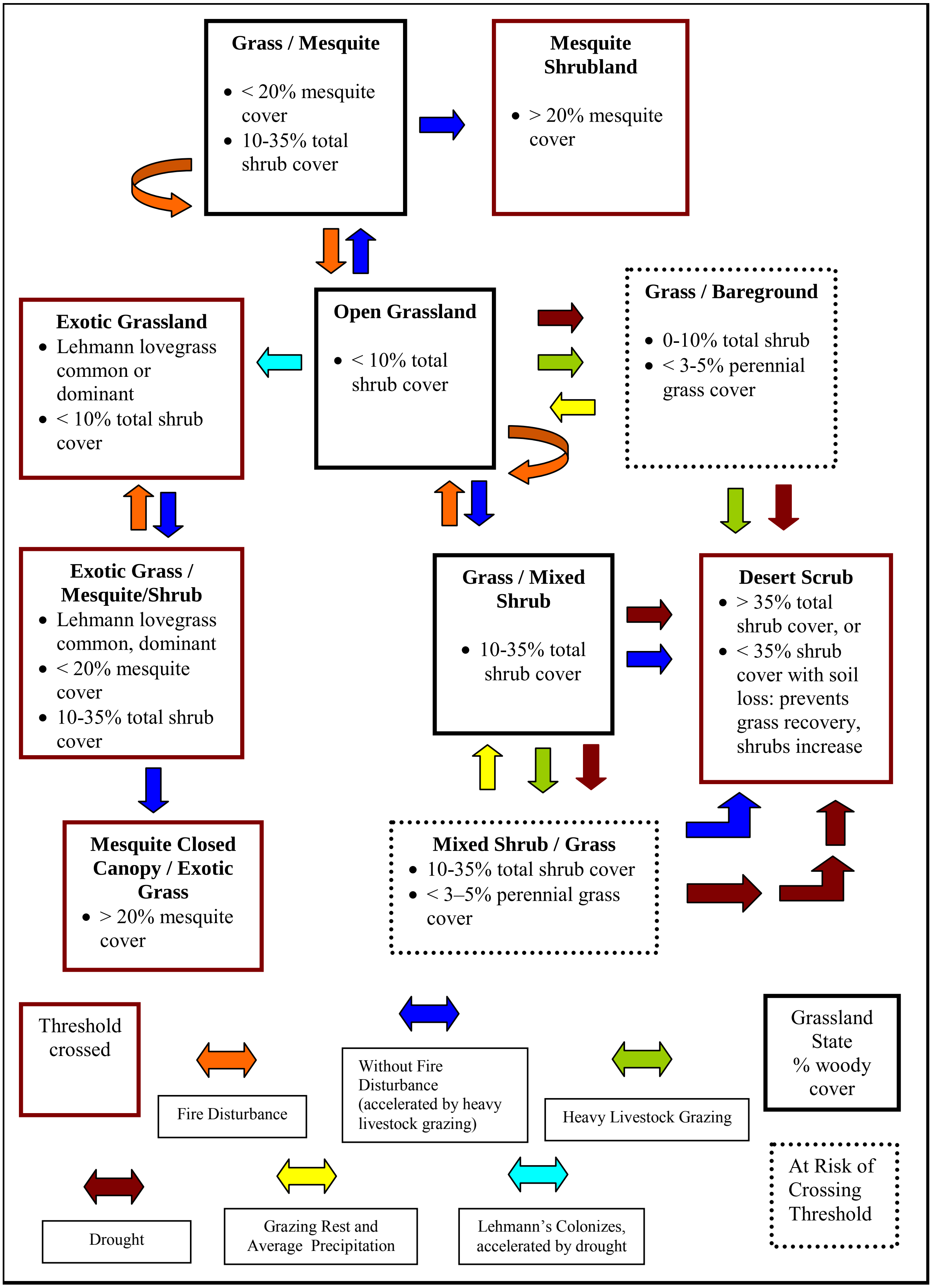


Figure 5. State and transition model for the semidesert grassland community at LCNCA. Boxes with black borders represent vegetation states that are within the historic range of variability (HRV) for grasslands; those with dashed borders depict states that are at extreme risk of type conversion to shrubland but still within HRV. Boxes bordered in brown depict vegetation states that have crossed a threshold that can only be reversed with an extraodinary input of resources.

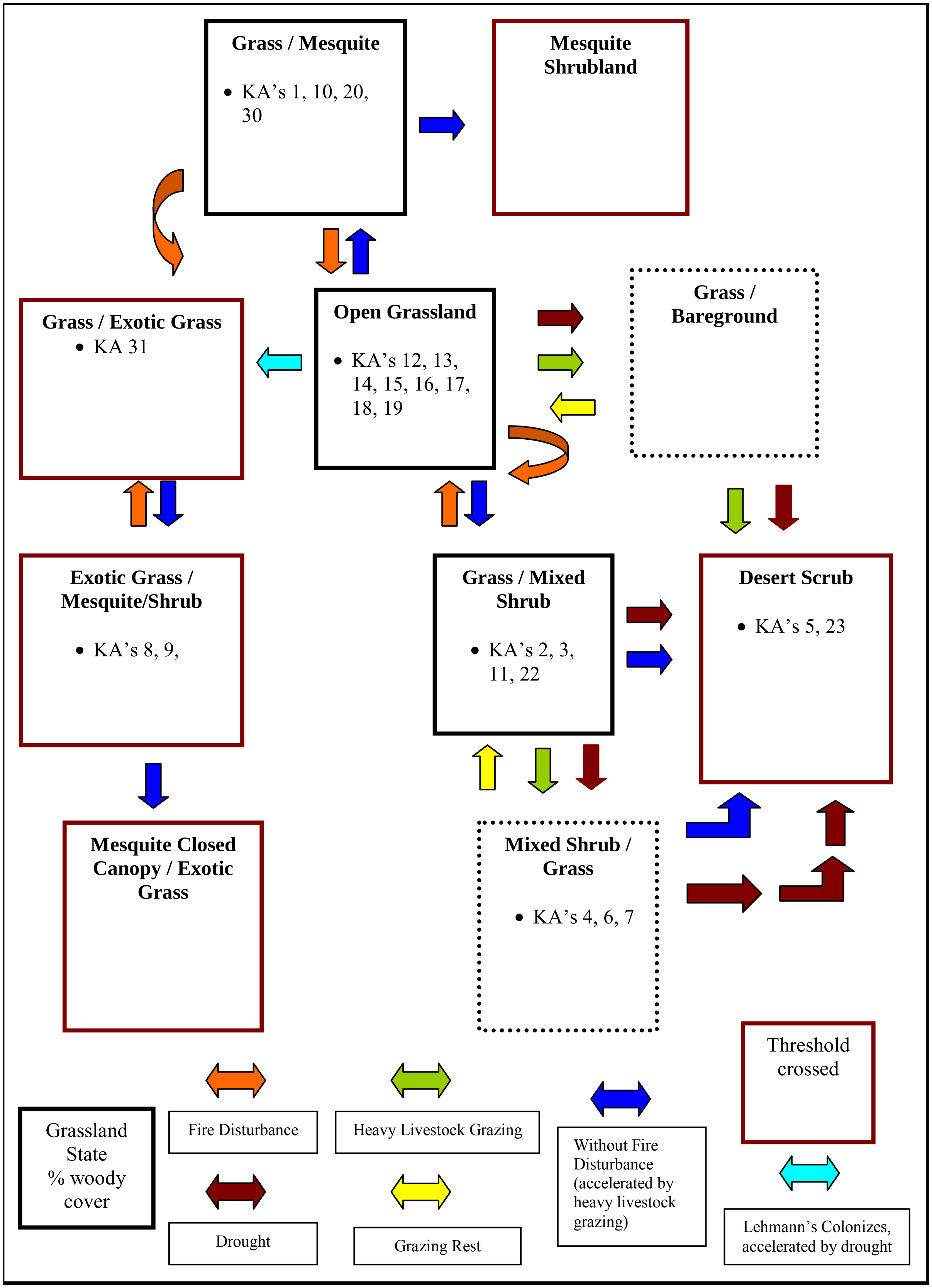


Figure 6. Key areas by vegetation state within the state-and-transition model for the semidesert grassland community at LCNCA. See text and Figure 3 for further explanation.

Because of the aerial extent of shrub encroachment and the high per-acre cost of mechanical/chemical treatment, prescribed fire may be the preferred management approach in areas where Lehmann lovegrass is absent or rare, allowing extensive areas to be treated at a relatively low cost. Restoration of fire will prevent further shrub encroachment, continued declines in perennial grass due to competition with shrubs, and type conversion.

Season of fire has strong effects on shrub mortality and the response of semidesert grasslands to fire (McPherson and Weltzin 2000). In general, prescribed burns conducted when historic wildfires occurred (early summer, pre-monsoon) produce the greatest reduction in cover and density of shrubs, including mesquite, while out-of-season fires (spring, fall, winter) produce significant mortality only in a few herbaceous plants such as Plains lovegrass (*Eragrostis intermedia*). However, because out-of-season fires represent a novel disturbance regime to which grassland fauna have not had the evolutionary opportunity to adapt, they may produce unforeseen and negative effects, potentially threatening biodiversity more than the absence of fire (G. McPherson, pers. comm.).

BLM is initiating a prescribed fire program in 2006; the above information for key areas will be useful in selecting areas in need of prescribed fire treatment.

SPREAD OF LEHMANN LOVEGRASS

There has been a significant increase in Lehmann lovegrass presence on key areas between 1995 and 2004 ($X^2 = 4.4$, 1 df, $p = 0.04$; Table 6). In 1995 (or when first monitored), Lehmann lovegrass was present in 5 out of 23 key areas (22%) whereas in 2004, it was present in 13 of 23 key areas (57%). An evaluation of dominance, based on the total canopy cover of Lehmann lovegrass in 2004, showed that only 2 key areas (9 and 31) were heavily invaded, with > 9% canopy cover of the species (Table 6). All other key areas with Lehmann present showed only low levels of invasion, with < 2% canopy cover.   Key areas 9 and 31 are located on sandy loam ecological sites which is consistent with our current understanding that Lehmann lovegrass spreads most easily to and becomes dominant on these sites (Cox and Ruyle 1986). However, the low level, but significant spread to other ecological sites warrants concern, continued monitoring, and a consideration of treatment options by BLM and the TRT.

CLIMATE AND DROUGHT AS POSSIBLE DRIVERS OF GRASSLAND CONDITION

The previous analyses indicated declining conditions on 48% of the key areas monitored since 1995 (or the date of first measurement) and that currently 66% of the key areas were *moderately* or *greatly outside desired condition* for 10 grassland condition indicators. In general, monitoring does not indicate causal factors for trends or changes in monitoring variables because controls that permit distinguishing different drivers for change are rarely established as part of the monitoring design. However, there is some available information on two of the possible contributors to vegetation change in desert

Table 6. Comparison of Lehmann lovegrass presence and abundance for key areas identified as sensitive to livestock grazing from 1995 to 2004. Values for 1995 to 2003 come from frequency sampling whereas the 2004 value is a canopy cover estimate obtained from point-intercept cover sampling. Trace abundance (T) was recorded if Lehmann was not encountered in frequency quadrats but was present in the key area; NR denotes not present or recorded in the key area. Gray shading indicates key area was not monitored that year.

Key Area	Ecological Site	1995	1998	1999	2000	2001	2003	2004
		% Freq	% Freq	% Freq	% Freq	% Freq	% Freq	% Cover
KA1	Loamy Upland	T	2	6				0.4
KA2	Loamy Hills	NR	NR	NR	NR			0.1
KA3	Loamy Hills	NR	NR	NR	NR			NR
KA4	Limy Slopes	1	NR	NR	NR			NR
KA5	Shallow Upland	NR	NR	1				NR
KA6	Limy Slopes	2	0	1				0.4
KA7	Volcanic Hills	NR	NR	NR				NR
KA8	Sandy Loam Upland	2	6	3	10	13		1.2
KA9a	Sandy Loam Upland	88	59	90		92		19.6
KA10	Loamy Bottom Swales	NR	NR	NR		NR		0.1
KA11	Loamy Hills	NR	NR	NR		NR		0.2
KA12	Loamy Hills	NR	NR	NR		NR		1.6
KA13	Loamy Upland		NR	NR		NR	1	NR
KA14	Loamy Bottom Swales		NR	NR		NR	1	2.1
KA15	Limy Slopes		NR	NR		NR	NR	0.5
KA16	Loamy Upland		NR	NR	NR		NR	NR
KA17	Loamy Upland	NR	NR	NR	NR			0.2
KA18	Loamy Upland	NR	NR	NR	NR			NR
KA19	Loamy Bottom Subirrigated	NR	NR	NR	NR		NR	NR
KA22	Limy Slopes	NR		NR	NR			NR
KA23	Basalt Hills	NR		NR				NR
KA30	Loamy Upland			NR	NR	NR		0.5
KA31	Sandy Loam Upland				6	30	28	9

grasslands, climate and livestock grazing, that may assist in evaluating their effects on grassland condition on LCNCA. With respect to climate and drought, precipitation was recorded quarterly at 18 rain gauges from October, 2000, to October, 2004, and continuously at another gauge established in 1988; together these gauges provide rainfall data for 21 of the 30 key areas (Table 7). Although extensive, the record is not perfect; precipitation records were missing for one or more readings for 6 of the 19 rain gauges used in this analysis. [When this report was being finalized, the authors became aware of another continuously recording gauge on LCNCA with precipitation records starting in 1988 and applicable to one key area; this station will be included in future analyses of upland monitoring data.]

Table 7. Summary of precipitation, in inches, recorded from rain gauges on the Empire Cienega Allotment between October 2000 and October 2004. Annual totals (October through September) are given in bold. Values with an asterisk (*) do not include the 1-2 inches received at the end of September from tropical storm Marty. Rain gauge vandalized is indicated with a V; NR indicates rain gauge not read. Blank cells may represent no rainfall, rain gauge not read, or rain gauge tampered with; no explanatory notes were given to authors to assist in the interpretation of these missing values.

Pasture or Location	Key Area	10/00 - 5/01	6/01- 9/01	**2001 Total**	10/01 - 5/02	6/02- 9/02	**2002 Total**	10/02 - 5/03	6/03- 9/03	**2003 Total**	10/03 - 5/04	6/04 - 10/04	**2004 Total**
Apache	27	16	11	**27**	2	10.5	**12.5**	5		**5**	8.4	5.5	**13.8**
East Davis	15	13	8.5	**21.5**	2	7.5	**9.5**	5	6.8 *	**11.8**	8.4	9	**17.4**
Five Wire	19	14	11	**25**	2	6.5	**8.5**	4.3	7.3 *	**11.6**	8.4	6	**14.4**
Fresno	22	13	13	**26**	2	6.3	**8.3**	3.3	6.3 *	**9.6**	8.4	6	**14.4**
Heart S Ranch	13	16.7	NR	**16.7**	2	NR	**2**	4.5	9.7	**14.2**	8.4	7	**15.3**
Hummel House	9&10	16.7	6.6	**23.3**	2	6.5	**8.5**	5.5		**5.5**	8.4		**8.4**
Lower Mattie	20	14	12	**26**	2	6	**8**	3.8	5.5 *	**9.3**	8.4	7	**15.3**
North Springwater	30&31	16.7		**16.7**	2.4		**2.4**	5.5		**5.5**	8.4	4.5	**12.9**
North Well	4&5	18	14	**32**	2	12.5	**14.5**	7	7.5 *	**14.5**	8.4	4.5	**12.9**
Oak Tree	2&3	16	12	**28**	2	9.5	**11.5**	4.3	7.8 *	**12**	8.4	V	**8.4**
Road Canyon	11&12	14.5	10.5	**25**	2	7.5	**9.5**	5	6.8 *	**11.8**	8.4	5	**13.4**
Rockhouse	6&7	12.5	11	**23.5**	2	7.5	**9.5**	5.5		**5.5**	8.4	NR	**8.4**
Runway (Lower North)	8	15.5	11	**26.5**	2	11	**13**	4.3	6.8 *	**11.1**	8.4	4	**12.4**
South Springwater	16	14.5	11.5	**26**	2	8	**10**	4.5	9.3	**13.8**	8.4		**8.4**
Upper Mattie	21	15.3	12	**27.3**	2	7.5	**9.5**	4.8		**4.8**	8.4	6.5	**14.9**
West Davis	14	14.5	12	**26.5**	2	9	**11**	5	8.7 *	**13.7**	8.4	10	**18.4**
West Pasture	17&18	16.7	10.5	**27.2**	2.4	6.6	**9**	5.5	7.7	**13.2**	8.4	5.9	**14.3**

To evaluate the effects of precipitation during the last 4-years on grassland condition, summer and annual rainfall data were combined to give a 4-year summer and 4-year annual precipitation total for each of the gauges and then, based on these totals, key areas were operationally grouped into 1 of 3 categories: those receiving *above-average*, *average*, or *below-average* rainfall. Precipitation patterns in the Sonoita area are bimodal, with approximately half of the average annual rainfall coming in the summer (June through September) and the other half in the winter (October through May). The amount of summer and annual precipitation varies depending on location within the LCNCA. Because long-term records are lacking, we used the location of ecological sites within the LCNCA and their precipitation zones as a surrogate for determining average rainfall amounts. Ecological sites in the northern portion of LCNCA are mostly in the 12-16 inch precipitation zone, while ecological sites in the southern portion are split between the 12-16 inch and 16-20 inch precipitation zones. Given the two precipitation zones, the average 4-year annual rainfall range would be 48 to 64 inches (mean = 56”) for ecological sites in the 12-16 inch zone, and 64 to 80 inches (mean = 72”) for ecological sites in the16-20 inch zone (Table 4). Assuming that roughly half of the rainfall comes in the summer, the 4-year summer rainfall range would be 24 to 32 inches (mean = 28”) and 32 to 40 inches (mean = 36”) for ecological sites in the 12-16 inch and 16-20 inch zones, respectively.

Based on the above information, threshold values for *below-average*, *average* and *above-average* summer and total rainfall for the 4-year period were derived and are summarized in Table 8.

Analysis of the combined summer and total precipitation for the past 4 years showed a consistent pattern between summer and annual totals within key areas (Table 9). That is, key areas receiving *above-average* summer precipitation also received *above-average* total precipitation while key areas with *below-average* summer precipitation also received *below-average* total precipitation. There was only 1 exception to this pattern, key area 13 which received *below-average* summer precipitation but *average* total precipitation for the 4-year period. Using the threshold values in Table 8, 9 of 21 key areas (2, 6, 7, 9, 10, 11, 15, 30, and 31) were classified as receiving *below-average* precipitation, and 11 of 21 key areas (3, 4, 5, 8, 12, 14, 16, 17, 18, 19, and 22) were classified as receiving *above-average* precipitation for the 4-year period. Since the perennial grasses are primarily warm-season species and their productivity is tied to summer rainfall, key area 13 was classified overall as having received *below-average* precipitation for the 4-year period.

If grassland condition in 2004 was closely linked to precipitation, then key areas that were *within or slightly outside desired condition* for the 10 condition indicators should have received *above-average* rainfall over the 4-year period whereas key areas that were *moderately or greatly outside desired condition* should have received *below-average* rainfall. This predicted linkage is not clearly evident from the data (Table 10). Five of 10 key areas identified as *moderately or greatly outside desired condition* (50%) had

Table 8. Threshold precipitation values, in inches, used in classifying key areas into those receiving *below-average*, *average*, or *above-average* precipitation based on their 4-year summer and 4-year annual rainfall totals. The 4-year period of record runs from October 2000 to October 2004. Separate thresholds are given for ecological sites and key areas in two precipitation zones: 12-16" (A) and 16-20" (B). See text for further explanation.

A. 12-16" Precipitation Zone

4-Year Total Rainfall			4-Year Total Summer Rainfall		
Above Average	Average	Below Average	Above Average	Average	Below Average
> 56	48-56	< 48	>28	24-28	< 24

B. 16-20" Precipitation Zone

4-Year Total Rainfall			4-Year Total Summer Rainfall		
Above Average	Average	Below Average	Above Average	Average	Below Average
> 72	64-72	< 64	> 36	> 32-36	< 32

below-average summer and total rainfall compared to 4 out of 10 key areas that were *within or slightly outside desired condition* (40%). Including key area 13 in the former group, the number increases to 6 out of 11 key areas (55%). This difference is not significant (Fisher exact test, 1 df, p = 0.67).

Similarly, an analysis of variance also showed no significant difference between the three grassland condition groups in the amount of summer or total rainfall received over the 4-year period (total precipitation: $F_{2,18} = 0.27$, p = 0.78; summer precipitation: $F_{2,18} = 0.74$, p = 0.49). Interestingly, key areas that were *within or slightly outside desired condition* had the highest mean summer (28.4") and highest mean total rainfall (58.4") over the 4-year period, followed by key areas that were *greatly outside desired condition* (at 22.2", summer, and 56.2", total, respectively), but these differences were not significant. There were also no significant correlations between any of the condition indicator variables and 4-year summer precipitation and 4-year total precipitation (Table 11). Overall, these analyses fail to show a strong connection between rainfall over the last 4 years and the combined grassland condition indicators for 21 key areas.

Similarly, there was no difference in 4-year summer precipitation or 4-year total precipitation between key areas that met vs. those that did not meet the threshold value for perennial grass cover in 2004 (4-year summer precipitation: Mann-Whitney $U = 25.5$, p = 0.54; 4-year total precipitation: $U = 26.5$, p = 0.6, n = 16 key areas that met, n = 4 that did not meet). In addition, there was no difference in 4-year total precipitation between

Table 9. The total amount of summer and annual precipitation, in inches, received over a 4-year period, October 2000 to October 2004, for 23 key areas evaluated for grassland condition. Key areas with below-average precipitation for this period are shaded dark gray, those with average precipitation are light gray, and those with above-average precipitation are unshaded. See table 8 for determining above- and below-average precipitation thresholds.

Key Area	Ecological site	4-Year Total Summer Precipitation (inches)	4-Year Total Precipitation (inches)
1	Loamy upland 12-16"	No data	No data
2	Loamy hills 16-20"	29.3	59.9
3	Loamy hills 12-16"	29.3	59.9
4	Limy slopes 12-16"	38.5	73.9
5	Shallow upland 12-16"	38.5	73.9
6	Limy slopes 12-16"	18.5	46.9
7	Volcanic hills 12-16"	18.5	46.9
8	Sandy loam upland 12-16"	32.8	67.8
9	Sandy loam upland 12-16"	13.1	45.7
10	Loamy bottom swales T16-20"	13.1	45.7
11	Loamy hills 16-20"	29.3	59.1
12	Loamy hills 12-16"	29.3	59.1
13	Loamy upland 12-16"	16.7	48.2
14	Loamy bottom swales T16-20"	39.7	69.5
15	Limy slopes 16-20"	31.8	60.1
16	Loamy upland 12-16"	28.8	58.1
17	Loamy upland 12-16"	28.8	61.8
18	Loamy upland 12-16"	30.6	61.8
19	Loamy bottom subirrigated 12-16"	30.8	59.4
22	Limy slopes 12-16"	31.5	58.1
23	Basalt hills 12-16"	No data	No data
30	Loamy upland 12-16"	4.5	37.5
31	Sandy loam upland 12-16"	4.5	37.5

key areas that met vs. those that did not meet RMP objectives for bare ground cover or the Similarity Index value in 2004 or when last measured (U = 50.5, p = 0.26, n = 15 key areas that met, n = 5 that did not meet). However, key areas that didn't meet RMP objectives received significantly less summer precipitation over the 4-year period than key areas that met them (17.7 + 10.8 (SD) inches vs. 27.9 + 9.6 inches, respectively; U = 63.5, p = 0.023). This result for summer precipitation may be due to the proportionately greater number of missing precipitation records among key areas that didn't meet RMP objectives. That is, 3 of 5 key areas (60%) that didn't meet objectives had 1 to 3 summer records missing over the 4-year period compared to 6 of 15 key areas (40%) that met objectives (Table 7).

Table 10. Comparison of grassland condition and amount of rainfall received over a 4-year period (October 2000 to October 2004) for 21 key areas with rainfall data. No shading indicates *within or slightly outside desired condition* for grassland condition or *above-average* precipitation; light grey denotes *moderately outside desired condition* for grassland condition; and dark shading denotes *greatly outside desired condition* or *below-average* precipitation. See text for further explanation.

Ecological site	Key Area	Grassland Condition	Rainfall	Correspondence: Drought & Condition
Loamy hills	2			No
Loamy hills	3			Yes
Limy slopes	4			No
Shallow upland	5			No
Limy slopes	6			Yes
Volcanic hills	7			Yes
Sandy loam upland	8			No
Sandy loam upland	9			Yes
Loamy bottom swales	10			Yes
Loamy hills	11			No
Loamy hills	12			Yes
Loamy upland	13			Yes
Loamy bottom swales	14			Yes
Limy slopes	15			No
Loamy upland	16			No
Loamy upland	17			No
Loamy upland	18			Yes
Loamy bottom subirrigated	19			Yes
Limy slopes	22			Yes
Loamy upland	30			No
Sandy loam upland	31			Yes

Even if one assumes there are errors in our classification of key areas into those receiving *above*- or *below-average* rainfall based on their ecological sites, in the absence of better data, ecological sites do provide an objective way of stratifying key areas into those receiving relatively more vs. relatively less rainfall over the last 4 years. More significant are the small number of key areas that could be used in the analysis and the number of missing rainfall records due to vandalized or unread rain gauges which decrease the overall confidence in the above results (Table 7). In addition, some vegetation changes,

Table 11. Coefficients and associated probability values for correlations between precipitation and selected grassland condition indicators for 21 key areas in LCNCA. None of the correlations were significant.

Precipitation	Condition Indicator	Correlation Coefficient (r)	Probability, 2-tail
4-year summer total	% perennial grasses trending down, 1995-2003	- 0.02	0.92
	% shrub cover	0.19	0.41
	% mesquite cover	- 0.30	0.19
	% perennial grass basal cover (2004)	0.10	0.66
	% bare ground cover, 2004	- 0.27	0.24
	Similarity Index, last measurement	0.36	0.31
	No. of indicators outside of desired values (thresholds)	-0.31	0.17
4-year total	% perennial grasses trending down, 1995-2003	0.07	0.76
	% shrub cover	0.21	0.37
	% mesquite cover	- 0.25	0.28
	% perennial grass basal cover, 2004	0.06	0.79
	% bare ground cover, 2004	- 0.23	0.32
	Similarity Index, last measurement	0.35	0.33
	No. of indicators outside of desired values (thresholds)	- 0.23	0.31

such as increases in shrub and or tree cover, or recovery of perennial grass cover happen over longer periods of time than 4 years. Hence, recent precipitation may be less important in explaining the current condition of key areas than past precipitation (or land use) is. In addition, there are other climatic factors which are not being monitored, such as precipitation intensity, timing of rainfall, temperature, and evaporation potential, which ultimately influence water availability to plants and can potentially affect vegetation change (Loik et. al. 2004). Given the relatively short precipitation record for the Empire Cienega Allotment, issues with consistency in data collection, and general difficulty of attributing vegetation change to recent precipitation patterns, we now focus on other available information to help evaluate climatic effects on key area/grassland condition.

LIVESTOCK EXCLOSURES: DISENTANGLING THE EFFECTS OF CLIMATE AND GRAZING

Where livestock grazing is occurring, the establishment of side-by-side or nearby fenced exclosures can assist in the interpretation of vegetation changes in key areas because climate, a major driver in vegetation change, is similar inside and outside the fenced area.

Hence, if vegetation conditions are poor inside and outside an exclosure, the poor condition is most likely due to climatic factors, such as precipitation, affecting both areas rather than livestock grazing which is affecting only the area outside the exclosure.

Two pairs of key areas, one inside and the other outside a fenced exclosure, were sampled in 2004. (We will refer to fenced and unfenced key areas as "ungrazed" and "grazed" by livestock, respectively, although we realize that both areas are subject to grazing and browsing by native herbivores such as rabbits and deer that are not deterred by the fence.)

The exclosure in West pasture was established approximately 25 years ago by the USDA Agricultural Reseach Service in a loamy upland site for a precipitation run-off study. In 1995, side-by-side key areas were set up and measured: key area 18 inside the exclosure and key area 17 outside. Substrate cover and vegetation were similar in some respects and different in others in the 2 areas in 1995 (Table 12). Bare ground cover was significantly *higher* and litter cover was significantly *lower* in the ungrazed key area compared to the grazed one in 1995. However, there was no difference in live basal vegetation cover in the two plots, but a difference in composition: blue grama (*Bouteloua gracilis*) and curly mesquite (*Hilaria belangeri*) were both common perennial grasses in the grazed area in 1995 whereas the ungrazed key area was dominated by blue grama, sideoats grama (*B. curtipendula*) and 3-awn species (*Aristida* sp.). In addition, perennial grass diversity was greater on the ungrazed area perhaps due to 15 years of prior livestock exclusion and/or to subtle (non-evident) topographic difference between the adjacent key areas.

Differences between the key areas were greater by 2004 (Table 13). Bare ground cover was significantly lower in the ungrazed area while the basal cover of live herbaceous vegetation and of perennial grasses were both significantly greater in the ungrazed area compared to the grazed one. For perennial grasses, basal cover was significantly greater on the ungrazed area compared to the ungrazed area as was the basal cover of mid- and tall-statured bunch grasses (3.5 times higher on the ungrazed area). Perennial grass

Table 12. Comparison of two, side-by-side key areas in 1995 when they were first sampled; key area 17 is grazed while key area 18 is fenced and excluded from livestock grazing. Fisher exact tests were used in all comparisons of cover between grazed and ungrazed key areas. Non-significant comparisons are designated by NS. Significance levels are given for significant comparisons: * p < 0.05, ** p < 0.01, *** p < 0.001.

Variable	Key Area 17 (Grazed)	Key Area 18 (Livestock Excluded)	Significance
% Bare ground cover	13	24	*
% Litter cover	68	52	*
% Live vegetation cover (basal)	12	11	NS
Common perennial grass species [1.]	Bouteloua gracilis; Hilaria belangeri	B. gracilis; B. curtipendula; Aristida sp.	
No. perennial grass species [1.]	6	10	

[1.] Determined from frequency sampling data

Table 13. Comparison of the same, side-by-side key areas in 2004 when they were last sampled; key area 17 is grazed while key area 18 is excluded from livestock grazing. Fisher exact tests were used in all comparisons of cover between grazed and ungrazed key areas, except for shrub cover where a Kruskal-Wallis test was used. Non-significant comparisons are designated with NS. Significance levels are given for significant comparisons: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Variable	Key Area 17 (Grazed)	Key Area 18 (Livestock Excluded)	Significance
% Bare ground cover	32.7	19.4	***
% Litter cover	52.5	54	NS
% Live Vegetation cover (basal)	12.8	17.8	**
% Perennial grass cover (basal)	12.4	17.8	**
Common perennial grasses	Bouteloua gracilis	B. gracilis; B. eriopoda; B. curtipendula	
% Mid- & tall-statured bunchgrass cover (basal)	1.5	6.8	***
No. perennial grass species	11	13	
% Shrub cover (canopy)	6.6	5.8	NS
Mesquite density (> 1 m height) (No. per hectare)	32	10	
Mesquite density (< 1 m height) (No. per hectare)	48	16	

composition continued to differ: blue grama was dominant on the grazed area, while blue and sideoats grama persisted in being common on the ungrazed area with an apparent increase in the abundance of black grama (*B. eriopoda*) over the 10-year period. Canopy cover of all shrubs was similar in the two key areas, although the density of mesquites was higher in the grazed area. Thus, there have been significant changes in substrate (bare ground, litter) and perennial grass cover over the 10-year period (1995-2004) in the two areas suggesting less-than-desirable impacts by livestock at the site. Although the two plots are close to water, such that key area 17 receives greater than intermediate use, livestock use of key area 17 appears to be representative of the loamy upland portions of the pasture where cattle spend most of their time (D. Robinett, pers. comm.).

The exclosure in Spring Water pasture was established in 1999. In 2000, the adjacent key areas were set up in a loamy upland site and measured, key area 30 inside the exclosure and key area 31 outside (Table 14). Substrate cover and vegetation composition were different in the 2 key areas in 2000. Bare ground cover was significantly lower and cover by gravel and rock was significantly higher in the ungrazed area compared to the grazed one in 2000. There was, however, no difference in live basal vegetation cover in the two areas and litter cover was significantly greater in the grazed area. Furthermore, both areas were dominated by sprucetop grama (*B. chondrosioides*) with black grama also common in the grazed area and hairy grama (*B. hirsuta*) and 3-awn species common in the ungrazed area. The number of perennial grass species was equal in the two key areas.

Table 14. Comparison of two, side-by-side key areas in 2000 when they were first sampled; key area 31 is grazed while key area 30 is fenced and excluded from livestock grazing. Fisher exact tests were used in all comparisons of cover between grazed and ungrazed key areas. Non-significant comparisons are designated by NS. Significance levels are given for significant comparisons: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
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Variable	Key Area 31 (Grazed)	Key Area 30 (Livestock Excluded)	Significance
% Bare ground cover	42	17	***
% Gravel & rock cover	15	50	***
% Litter cover	39	27	**
% Live vegetation cover (basal)	4	6	NS
Common perennial grass species [1.]	B. chondrosoides; B. eriopoda	B. chondrosoides; B. hirsuta; Aristida sp.	
No. perennial grass species [1.]	6	6	

[1.] Determined from frequency sampling data

Differences in bare ground, rock and gravel cover between the two areas persisted through 2004 (Table 15). However, live basal vegetation cover increased significantly on the ungrazed area between 2000 and 2004 (Fisher exact test, $p = 0.04$) and was 2 times higher on key area 30 (ungrazed) compared to key area 31 (grazed) in 2004. Basal cover of perennial grasses was also significantly greater in the ungrazed area as was the basal cover of mid- and tall-statured bunch grasses (i.e., 3.7 times higher in the ungrazed area vs. the grazed area in 2004). The number of perennial grass species was also higher on the grazed area. Perennial grass composition continued to differ in the two key areas: Lehmann lovegrass now dominated in the grazed area, a change from 2000, with blue and black gramas also common, whereas sideoats grama replaced 3-awn species as common in the ungrazed area. It is unclear whether these apparent compositional changes from 2000 to 2004 are the result of different sampling methods (i.e., frequency sampling in 2000 and point-intercept sampling in 2004 over a larger area) or vegetation changes occurring in response to grazing and grazing rest at the site. There was no difference in the canopy cover of shrubs in the two areas, but the density of mesquite was significantly greater in the grazed area; the latter pattern is opposite to what was observed in the other paired key areas (e.g., 17 and 18).

To summarize, there are potential problems with the placement of grazed and ungrazed key areas with respect to the location of livestock water (e.g., 17 and 18) and substrate differences between key area pairs (e.g., 30 and 31). However, the results generally indicate that conditions are improving on the ungrazed key areas with decreases in bare ground cover, increases in live herbaceous vegetation and perennial grass cover, and increases in perennial grass diversity. This improvement is not being observed on adjacent grazed key areas.

Unfortunately, with only two exclosures it is difficult to determine the effects of livestock grazing and climate patterns elsewhere on the allotment. Due to this gap in information, the BLM's Technical Review Team has identified sites for additional exclosures. For more information on this process see section III, this report. In addition to the exclosures on the Empire Cienega Allotment, there are 3,141 acres of comparable semidesert

Table 15. Comparison of the same, side-by-side key areas in 2004 when they were last sampled; key area 31 is grazed while key area 30 is excluded from livestock grazing. Fisher exact tests were used in all comparisons of cover between grazed and ungrazed key areas, except for shrub cover where a Kruskal-Wallis test was used. Non-significant comparisons are designated by NS. Significance levels are given for significant comparisons: * p < 0.05, ** p < 0.01, *** p < 0.001.

Variable	Key Area 31 (Grazed)	Key Area 30 (Livestock Excluded)	Significance
% Bare ground cover	47.3	23.2	***
% Gravel & rock cover	29.6	46.4	***
% Litter cover	17	18.6	NS
% Live vegetation cover (basal)	5.8	11.6	
% Perennial grass cover (basal)	5.3	11.3	***
Common perennial grasses	E. lehmanniana; B. chondrosioides; B. eriopoda	B. chondrosioides; B. hirsuta; B. curtipendula	
% Mid- & tall-statured bunchgrass cover (basal)	0.3	1.5	**
No. perennial grass species	6	12	
% Shrub cover (canopy)	5.1	13.6	
Mesquite density (> 1 m height) (No. per hectare)	78	848	
Mesquite density (< 1 m height) (No. per hectare)	54	680	

grassland that is ungrazed by livestock on the Appleton-Whittell Area of Critical Environmental Concern (ACEC), which makes up the southern portion of LCNCA. The Audubon Research Ranch (ARR) has collected grassland monitoring information on the ACEC annually since 2002, including plant frequency by species, substrate cover, Similarity Index rating, and precipitation. While this information was unavailable for comparison with the results presented here, it will likely be available in the future and will assist BLM in evaluating the effects of climate and livestock grazing management on the LCNCA.

LIVESTOCK GRAZING MANAGEMENT

Pasture use from 1993 to 2004 was also evaluated in an effort to tease out connections between grassland condition and livestock grazing. Two key factors were analyzed for pastures containing key areas: frequency of livestock use and intensity of use. Frequency of use, or its inverse, was defined as the number of years a pasture was rested over the last 12 years, while intensity of use was calculated as the number of livestock days per pasture for each year and for the entire 12-year period (Table 16). (The number of livestock days per year for a pasture is simply the number of bulls and cow/calf units in the pasture multiplied by the number of days they spend there.)

In terms of frequency of use, 5 of 13 pastures with key areas were rested for 5 to 7 years of the past 12 years, 7 of 13 pastures were rested 2 to 4 years, and the remaining 3 pastures were rested only once in the last 12 years (Table 11). There was no significant difference between key areas that were *within or slightly outside desired condition*, those that were *moderately outside desired condition* and key areas that were *greatly outside desired condition* in the mean number of years their pastures had been rested. (ANOVA, $F_{2,17} = 0.14$, $p = 0.87$). That is, North Pasture, which was rested 3 of the past 12 years, has 4 key areas with 1, 2, 3, and 7 condition indicators outside of threshold values. On the other hand, Davis, Hilton, and 5 Wire pastures, which have been used 11 of the last 12 years, have 6 key areas and 4 of these had no indicators outside of threshold values. The remaining 2 key areas, 12 and 13, had only 1 and 2 condition indicators outside of threshold values, respectively, and in the case of 13, one of these indicators was its failure to meet the bare ground objective in 1995; it did meet it in 2004.

Results of the intensity analysis, performed on log-transformed data to normalize variances, also showed no effect of grazing intensity (e.g., number of animal use days in 12-years) on grassland condition (ANOVA, $F_{2,17} = 0.27$, $p = 0.77$; Table 16). That is, pastures with the greatest number of livestock days for the 12-year period (e.g., > median livestock use for pastures with key areas) had key areas that were *greatly outside desired condition* (8 and 31), *moderately outside desired condition* (3, 4, 6, 7, 13, and 16), and *within or slightly outside desired condition* (2, 11, and 12) [Tables 2, 16]. The results are similar if grazing intensity is adjusted or normalized by pasture size to capture grazing pressure or intensity on a per acre basis (e.g. number of animal use days in 12-years per acre; ANOVA $F_{2,17} = 0.77$, $p = 0.48$).

At first glance this suggests that the frequency or intensity of pasture use has had little effect on grassland condition. However, since the productivity of pastures varies considerably from the northern to southern end of the allotment, average precipitation and ecological site are critical factors that also need to be considered when evaluating the effect of the frequency or intensity of livestock use on a key area. However, due to a limited numbers of key areas per ecological site, we could not perform the analysis using ecological site as a covariate. Instead, we used a coarse-scale proxy for productivity, the NRCS's precipitation zones. Key areas were divided into two groups based on whether they were located on ecological sites in the 12-16" or 16-20" precipitation zone. We then compared the two groups with respect to the total number of condition indicators outside of desired thresholds, frequency of livestock use, and intensity of use.

The mean number of condition indicators outside of desired thresholds was significantly greater for key areas located in the 12-16" precipitation zone compared to those located in the 16-20" precipitation zone (t-test on ln transformed data; $t = 2.7$, 21 df, $p = 0.02$). That is, key areas in the 12-16" zone had 2.8 + 2.1 (SD) indicators outside of threshold values compared to only 0.8 + 1.1 for key areas in the 16-20" zone. All 5 key areas that were *greatly outside desired condition* were located in the 12-16" precipitation zone (Table 17). In addition, there was a marginally significant association between key areas in relatively poor condition, defined as having greater than the median number of indicators outside of threshold values, and lower average rainfall (Fisher exact test, one-tailed, $p = 0.07$). That is, 7 out of 17 key areas (41%) in the 12-16" precipitation zone had > 2 condition indicators outside desired thresholds compared to 0 out of 5 in the 16-20"zone.

Table 16. Frequency of livestock use, in number of years pasture was rested since 1993, and intensity of livestock use, in animal days per year per pasture, for all pasture between 1993 and 2004. Pastures are listed in order of decreasing livestock use for the 12-year period. Pastures with key areas that are appropriate for evaluating grazing effects are highlighted in grey.

Pasture	Years Rested	1993 Animal Days	1994 Animal Days	1995 Animal Days	1996 Animal Days	1997 Animal Days	1998 Animal Days	1999 Animal Days	2000 Animal Days	2001 Animal Days	2002 Animal Days	2003 Animal Days	2004 Animal Days	Animal Days 12 year total
North	3	105,830		163,750	37,450	85,510		94,250	147,700		250,000	57,532	19,950	961,972
Apache	2	33,735	261,138	86,250	98,750	82,410		40,950	54,000	105,000		129,150	19,455	910,838
Mattie	3		138,477		66,250	113,440		40,950	54,000	105,000	175,000	124,130	83,810	901,057
Rockhouse	3	33,735		108,750	106,250	134,840	29,480			105,000	236,950	12,000	1,500	768,505
Hilton	1	105,530	6,325	55,450	117,500	44,100	14,945	99,520	36,000		73,500	188,230	23,250	764,350
Gardner Sacaton	1	100,340	118,864	32,500	61,250	19,600	11,390	17,000		103,000	135,550	31,500	16,500	647,494
Shipping	3	19,030	25,000	39,000	25,000		6,030	30,000	35,000			415,290	12,012	606,362
Mac's Sacaton	0	18,165	16,250	5,500	82,660	28,120	16,750	7,800	37,000	88,000	91,150	67,200	63,180	521,775
49	5	91,690		143,750		134,840	29,480		47,700			48,750	1,500	497,710
Hummell Sacaton	3		84,999	57,500	55,000	53,900		29,000	9,000	118,000	65,550		10,500	483,449
Hilton Sacaton	3	65,740	38,750	57,500	55,000	8,560			22,000	135,000	76,050		18,000	476,600
Springwater	4	21,625	42,011		144,790	19,600	49,500				9,450	67,200	74,210	428,386
5 Wire	1	49,305	38,750	25,000	25,000	28,890	10,050		27,000	108,000	68,250	27,300	8,250	415,795
Coldwater	4				87,500	10,700	16,080	26,000	12,000	17,000	175,000	39,900		384,180
Ag Fields	7				87,500	10,700	16,750				175,000		58,035	347,985
Johnson	5	76,120			57,500		8,040		71,000		31,500	73,030	24,200	341,390
Davis	1	37,195	13,000	47,950	86,250		28,810	15,520	35,000	6,345	38,850	2,100	26,250	337,270
No. 1	3	21,625	25,000	39,000	25,000	19,600	6,030	30,000	35,000		35,200			236,455
No.2	3	21,625	25,000	39,000	25,000	19,600	6,030	30,000	35,000		35,200			236,455
Empire	3	22,250	44,740	41,000		2,760	11,400	3,204			8,870	6,160	75,940	216,324
Orchard	4	19,030	25,000	39,000	25,000	19,600	6,030	30,000	35,000					198,660
500 ac W	6							12,000	30,000	70,000	39,900	9,810	15,000	176,710
Alamo Solo	4	17,300	4,560		18,750		23,450	21,800	13,000			31,500	39,750	170,110
Cieneguita	8								30,000	70,000	41,600		22,350	163,950
Oil Well	9	37,195									112,800		10,500	160,495
Fresno	7	33,735	977			31,030						84,900	9,600	160,242
500 Acre E	7							12,000	19,000	44,000	2,000		63,180	140,180
Test Hole	10		137,500											137,500
Maternity	5		28,276	2,700			6,030	30,000	35,368		14,160		7,500	124,034
500 Acre	9				50,000	10,700					47,250			107,950
Adobe	10											84,900	9,600	94,500

Table 16. Continued.

Pasture	Years Rested	1993 Animal Days	1994 Animal Days	1995 Animal Days	1996 Animal Days	1997 Animal Days	1998 Animal Days	1999 Animal Days	2000 Animal Days	2001 Animal Days	2002 Animal Days	2003 Animal Days	2004 Animal Days	Animal Days 12 year total
Bull	9							5,000		87,000	720			92,720
Fergeson	11											89,250		89,250
Bellota	8						8,710	20,000				31,500	26,750	86,960
Cottonwood Sacaton	10				42,500							31,500		74,000
Neck	11										65,550			65,550
Sacrifice Lane	11										65,550			65,550
Bill's	10										27,300	31,500		58,800
West	3		1,404	1,400		10,560	3,600	15,300	5,566	3,861		7,130	5,238	54,059
Rattlesnake	11										48,300			48,300
North Cieneguita I	10	7,500	40,250											47,750
Lower Mattie	11											45,000		45,000
49 Sacaton	10											39,900	2,580	42,480
North Cieneguita II	10											37,000		37,000
Rick's Sacaton	11											31,500		31,500
Bull Trap	6		6,560		7,560	2,400					5,856	1,050	8,050	31,476
Sacatons	11									25,000				25,000
Shipping	11									25,000				25,000
Jerry's Sacaton	9	7,500			7,560								1,566	16,626
Mattie Sacaton	11												9,600	9,600
Bulls	12													0

Table 17. Summary of key areas by condition class as a function of their precipitation zone, i.e., 12 to 16" vs. 16 to 20" zone. See text for further explanation.

Grassland Condition Class	12-16" Precipitation Zone	16-20" Precipitation Zone
Within or Slightly Outside	3, 12, 18, 19, 22	2, 11, 14, 15
Moderately Outside	1, 4, 6, 7, 13, 16, 17, 30	10
Greatly Outside	5, 8, 9, 23, 31	

However, there was no significant difference in frequency of use or intensity of livestock use for key area pastures that were in the 12-16" vs. 16–20" precipitation zones despite the lower overall productivity of the former pastures (t-tests; Frequency of use: t = 1.1, 18 df, p = 0.25; Intensity of use: t = 0.03, 18 df, p = 0.98). The results are similar for grazing intensity expressed on a per acre basis (t = 0.5, 18 df, p = 0.59). These results can be interpreted in a number of ways. For example, drought conditions over the last 7 to 9 years coupled with shrub encroachment may be adversely impacting pastures and key areas in the 12-16" precipitation zone more than pastures and key areas in the higher precipitation zone, independent of livestock use. Alternatively, the effects of livestock grazing during a drought are poorly understood and we cannot reject the possibility that the equal frequency and intensity of livestock use of pastures in the two zones is having a negative impact in the 12-16" zone.

Consistent with the latter interpretation, there was a marginally significant difference in grazing intensity between key areas that met vs. those that did not meet the perennial grass cover threshold in 2004 (Table 18). That is, key areas with < 5% basal cover of perennial grasses were grazed more intensively over the 12-year period than were key areas with greater perennial grass cover. Similarly, annual grazing intensity when the pasture was used was significantly greater for key areas that did not meet the perennial grass threshold. The results were similar when grazing intensity was adjusted for pasture size (Table 18). There was no difference in grazing frequency between the two groups (Mann-Whitney U-test, U = 24, p = 0.43).

In contrast to the above results, there was no significant difference in grazing intensity over the 12-year period or in annual grazing intensity between key areas that met vs. those that did not meet RMP objectives for bare ground or the Similarity Index value when last measured (Table 18). The results were similar when grazing intensity was adjusted by pasture size. Together, these results suggest that the basal cover of perennial grasses may be more sensitive to grazing pressure than bare ground cover or the Similarity Index value at least in the context of the pastures and key areas that currently fail to meet threshold values for these indicators. The results also suggest that greater livestock numbers over the 12-year period and greater annual grazing intensity when pastures were used may be contributing to the low perennial grass cover on key areas that did not meet the threshold for this indicator.

Table 18. Comparison of mean livestock use (± SD) for key areas that (1) met vs. did not meet RMP objectives for bare ground and/or Similarity Index values in 2004 or when last measured and (2) met vs. did not meet the threshold for basal cover of perennial grasses in 2004. See Table 3 for threshold values. Statistical comparisons were made with Mann-Whitney U-tests; significant comparisons are indicated in bold along with their significance levels. All other comparisons were non-significant (i.e. p > 0.10). Sample sizes differ from Table 2 because livestock use information was not available for all key areas.

Variable	RMP Objectives		Perennial Grass Cover Threshold	
	Met (n = 5)	**Did Not Meet** (n = 15)	**Met** (n = 16)	**Did Not Meet** (n = 4)
Grazing frequency (No. of years rested, 1993-2004)	3.3 (3.0)	3.6 (0.5)	3.4 (2.9)	3.5 (1.0)
Grazing intensity (No. of animal days 1993-2004)	587,043.5 (308,346.8)	408,582.6 (349,850.1)	**490,742.1** [a] (328,341.2)	**749,173.0** [a] (190,844.2)
Grazing intensity by pasture size (No. of animal days 1993-2004/acre	183.7 (304.8)	67.1 (39.9)	**154.1** (300.0) [b]	**156.3** (51.4) [b]
Annual grazing intensity (No. of animal days/year grazed)	63,395.8 (32,542.4)	48,250.5 (38,752.6)	**52,713.9** [b] (33,898.2)	**87,191.5** [b] (14,756.4)
Annual grazing intensity by pasture size (No. of animal days/year grazed/acre)	18.9 (27.4)	8.0 (4.9)	**15.6** (27.0) [c]	**18.4** (5.3) [c]

[a] Mann-Whitney U-test, U = 13.5, p = 0.078; [b] U = 10.5, p = 0.041; [c] U = 8.5, p = 0.025

However, this interpretation is complicated by the fact that shrub cover was significantly greater on key areas that did not meet the threshold for perennial grass cover in 2004 compared to those that did (25.1 + 11.7 % cover, vs. 13.8 + 9.8 %, respectively, t-test, t = 2.2, 21 df, p = 0.04). In contrast, there was no difference in shrub cover between key areas that met RMP objectives and those that did not meet objectives when last measured, but mesquite cover was significantly greater on key areas that did not meet RMP objectives (7.4 + 6.3 % on key areas that did not meet RMP objectives vs. 2.3 + 2.9 % on those that did; t = 2.7, 21 df, p = 0.015).

2.4 CONCLUSIONS

Together, the results of our analyses of trends and changes in substrate cover in key areas as well as our assessment of grassland condition indicate many of the key areas are in less than desirable condition. In fact, 48% of the key areas monitored since 1995 or 1998 show declining conditions in 1 or more substrate cover variables and currently 66% of key areas were *moderately* or *greatly outside desired condition* for 10 grassland condition indicators. Twenty-six percent of key areas failed to meet RMP objectives for bare ground cover and/or the Similarity Index value in 2004 (or when last measured) and another 22% of key areas did not meet the threshold value for perennial grass (basal) cover. This suggests the need for a closer evaluation of these keys areas to assess whether a change in management for the pasture or the area bounded by the ecological site is warranted through the established TRT and Range Resource Team (RRT) biological planning process. Although the majority of key areas can be assigned to state-and-transition model states that are within the natural (historic) range of variability for semidesert grassland, active management may be required to maintain or improve grassland condition, especially in key areas that are bordering on or moving toward a permanent type conversion due to shrub encroachment. In the Las Cienegas RMP, BLM prescribes a tool box of vegetation treatment strategies including prescribed fire, mechanical treatments, and livestock grazing rest that can be used to achieve desired upland condition (BLM 2003). Key areas with total shrub cover values ≥ 20% and/or mesquite cover values ≥ 15% (1-4, 6-10, 17-20, 22, 23, and 30) will need evaluation to determine the best vegetation management actions to reduce the cover of shrubs and trees. The same holds true for key areas (8 and 9) with high shrub and/or mesquite cover values that are invaded by Lehmann lovegrass; these areas will need evaluation to determine the most prudent vegetation management strategy that minimizes spread of the exotic grass while reducing shrub and/or mesquite cover. Finally, key areas with low basal cover of live herbaceous vegetation, low perennial grass cover, and high shrub cover (4, 6, 7, 22, and 31) will need evaluation to determine the most appropriate management actions for increasing cover by perennial grasses and other fine-fuels and reducing shrubs. Prescribed burning has been shown to be an effective tool for reducing shrubs and increasing perennial grass cover and forb density at other semidesert grassland sites (Gori and Backer, in press; Reynolds and Bohning 1956; Bock and Bock 1978; Valone and Kelt 1999).

Our results suggest that some combination of drought stress, site-specific factors including shrub encroachment, and livestock grazing may be driving the pattern of grassland condition seen across the allotment. However, given the small sample size of key areas, missing precipitation data, the lack of long-term precipitation records for different portions of the allotment, and the small number of exclosure locations, there is considerable uncertainty regarding which of these factors, either acting alone or in concert with others, is responsible for the current condition of grasslands on the Empire Cienega Allotment. Increasing the total number of livestock exclosures adjacent to unfenced key areas as well as increasing the power of the monitoring protocol to detect change, will assist BLM in disentangling the effects of livestock grazing, climate and site specific factors on grassland condition. This information will clarify the effect of livestock grazing during a drought on perennial grass recovery (during and post-drought) and will also assist BLM in setting thresholds appropriate for different ecological sites that will trigger a change in management. BLM's efforts through adaptive grazing management to evaluate stocking levels in context of current grassland condition and drought may also assist in improving grassland condition. Together, the advance in information regarding the connections between climate, prescribed burning, and livestock effects on grassland condition will help BLM refine management goals for upland watersheds and identify the appropriate management actions needed to achieve those goals, both of which will assist future adaptive management at LCNCA.

III. Adaptive Management At Work

3.1 Introduction

Many times land managers are forced to make land management decisions in the face of little or no information regarding the outcome of those decisions. Adaptive management is a process designed to change this through the collection of information that assists in evaluating the effects of management actions and in identifying knowledge gaps that can be addressed by research or additional monitoring. The result is a decision making process based on on-the-ground information. The Resource Management Plan (RMP) for LCNCA recognized adaptive management as integral to BLM's management of the area. Specifically, in regard to livestock grazing, the RMP states that authorized livestock use will be varied annually by the BLM based on forage availability and range conditions determined from monitoring data and other assessments.

The adaptive management process requires seven primary steps:

1. Identification of management goals and measurable thresholds in resource condition.
2. Development of a monitoring protocol with adequate sampling effort to detect biologically meaningful change in resource condition over a specified time period and an optimal frequency and timeframe during which monitoring should be conducted.
3. Consistent implementation of the monitoring protocol.
4. Analysis of data.
5. Review of data against established goals and thresholds to determine need for changes in management.
6. Implementation of needed management changes (and continued monitoring).
7. Implementation of follow-up scientific studies to fill identified information gaps.

Consistent with the above steps, the following is a summary of the adaptive management process for grazing management decision-making currently in use on the Empire Cienega Allotment at LCNCA.

The Adaptive Management Process

Following a six-year collaborative planning process with Sonoita Valley Planning Partnership (SVPP), a voluntary association of agencies, organizations, user groups and private citizens, BLM completed an RMP for LCNCA which included management objectives, condition thresholds, and monitoring protocols for upland watershed vegetation (e.g., semidesert grassland). A detailed analysis of the original monitoring plan revealed that to evaluate vegetation objectives as established in the RMP, the protocol would need to be enhanced. Specifically, the protocol needed additional monitoring parameters (i.e., measurement of shrub density and cover), an increase in sampling locations and sampling effort, and modifications to the sampling schedule (see Appendix A for detailed analysis).

Following completion of the protocol review, the monitoring plan was revised and field-tested by TNC and BLM staff between September and October, 2004. Key areas were prioritized and selected for measurement based on the lessee's proposed annual grazing plan to ensure that information collected would be germane to decision-making. The monitoring data was then synthesized by TNC and presented to BLM's Las Cienegas Technical Review Team (TRT) and Range Resource Team (RRT) on October 8th and October 22nd, 2004. The Las Cienegas TRT, consisting of technical experts from federal and state agencies including BLM, is responsible for evaluating the proposed livestock grazing plan in the context of the monitoring information and, if necessary, recommending adjustments in livestock numbers and pasture use. The Las Cienegas RRT, composed of representatives of user and interest groups, local government, academia and interested public, is a subcommittee of the Arizona Resource Advisory Council and provides a forum for public comment on the analysis and interpretation of monitoring data and TRT recommendations. The goal of this iterative team process is to provide peer review and allow different perspectives to be incorporated into the final grazing management decision.

Monitoring information summarized for 2004 included: (1) bare ground cover, basal and canopy cover of perennial grasses, shrub canopy cover, and dominant perennial grass and shrub species for 24 key areas (Table 19); (2) information on the proposed livestock grazing plan for winter 2004 and spring 2005; and (3) comparison of bare ground and perennial grass cover with summer precipitation records for 2001 to 2004 (Tables 20, 21). The TRT's review of the proposed grazing plan and monitoring data revealed concern over two pastures with proposed winter and spring use: 49 and Rockhouse. The concern was due to low basal cover of perennial grasses in 2004, a downward trend in live basal vegetation cover between 1995 and 2004, and relatively high shrub cover for key areas in the two pastures (Table 19). Based on the monitoring information and concerns of the TRT, the lessee revised his grazing plan and decreased by 2 months, or 50 %, the total amount of time that livestock would be grazing in these pastures. Specifically, the 300 head of livestock proposed to enter the 49 and Rockhouse pastures on December 1, 2004, were held on sacaton pastures until February 1, 2005, in an effort to decrease the overall time livestock were grazing these areas. In addition, the lessee used water sources strategically, keeping livestock on the sacaton portions of these pastures and away from more sensitive upland areas with lower perennial grass cover.

The RRT concurred with the TRT's recommendation following careful review of the monitoring data analysis. The BLM also concurred with these recommendations.

3.3 CONCLUSIONS

The BLM, the lessee, TRT, and RRT successfully completed steps 1 through 6 of the adaptive management process outlined above. In addition, the TRT and RRT, with BLM concurrence, identified the following information gaps or needs that would assist in future decision making (e.g., Step 7):

- Identify biologically important thresholds for basal cover of perennial grasses by ecological site including thresholds that may trigger a change in grazing management;
- Locate a rain gauge in the Rockhouse pasture in order to gather more accurate precipitation information for this area;

Table 19. Monitoring results for key areas potentially affected by grazing. Values for key areas not meeting the bareground objective or the desired basal perennial grass cover (> 10%) or shrub cover (< 12%) in 2004 are highlighted in grey, those meeting the objectives are highlighted in green and those pastures proposed for use from fall 2004 to spring 2005 are denoted in pink. Key areas in bold were monitored in 2004 using the revised protocols, other values for other key areas come from the date of last monitoring. Key area 20 was moved in 2004 from its original site.

Pasture	Exclosure	Key Area	Bareground basal cover	Perennial Grass basal cover	Perennial Grass canopy cover	Dominant Perennial Grass	Shrub canopy cover	Dominant Shrub species
5 Wire		**19**	23.9	19	82.9	Sacaton	4.3	Mesquite
Alamo Solo		**9**	36.4	10.5	21.8	**Lehmann's**	22.7	Mesquite, Burroweed
Davis		**14**	25.7	29.6	58.6	Blue grama	4.2	Unknown
Davis		**15**	16.2	22.5	75.4	Sideoats grama	6.6	Burroweed
Fresno		25	30	0	NA	NA	NA	NA
Fresno		**22**	26.4	5.9	16.6	Black grama	27.8	False mesquite
Hilton		**11**	7.2	20.3	56.3	Bullgrass	16.8	Burroweed
Hilton		**12**	18.1	11	32.3	Curly mesquite	8.3	Burroweed
Hilton		**13**	26.9	18.9	46.8	Blue grama	0.6	Catclaw acacia
Johnson		**10**	20.9	26.8	64.6	Blue grama	10.9	Mesquite
Lower Mattie		**20 ***	28.1	9.4	57.7	Sacaton	10.8	Mesquite
Mac's Sacaton	exclosure	**30**	23.2	11.3	26.4	Sprucetop grama	13.6	Mesquite, Burroweed
North		**2**	9.9	12.7	62.8	Sideoats grama	22.0	Oak, Juniper
North		**3**	13.1	7.5	47.5	Sideoats grama	23.6	False mesquite
North		**4**	21.5	4.2	12.4	Black grama	28.8	False mesquite
North		**8**	51.8	7.9	16.8	Blue grama	21.6	Mesquite, Burroweed
Rockhouse		**6**	13.5	4	20.5	Black grama	27.7	False mesquite, White thorn acacia
Rockhouse		**7**	19.4	3.8	13.5	Sideoats grama	27.4	False mesquite, White thorn acacia
Rockhouse		24	6	4	NA	Sacaton	NA	NA
Springwater		**16**	22.3	20.4	35.7	Sprucetop grama	6.0	Shrubby Buckwheat
Springwater	outside	**31**	47.3	5.3	18.7	**Lehmann's**, Black grama	5.1	Range ratany
Trap #1		**1**	51.4	9.5	22.8	Blue grama	10.6	Burroweed
Triangle		**23**	10	1.7	16.6	Tobosa	36.4	False mesquite, White thorn acacia
Upper 49		**5**	16.5	2.8	8.7	Black grama	36.1	White-thorn acacia, False indigo bush
West	outside	**17**	32.7	12.4	31.3	Blue grama	6.6	Catclaw acacia
West	exclosure	**18**	19.4	17.8	49	Blue grama, Black grama, Sideoats grama	5.8	Mesquite, Burroweed

Table 20. Summer precipitation recorded for pastures and key areas from 2001 to 2004 as well as the 4-year cumulative summer total. Key areas not meeting bare ground objectives in 2004 are highlighted.

Location or Pasture	Key Area	6/01-9/01	6/02-9/02	6/03-9/03	6/04-10/04	4-Year Summer Total
Empire Headquarters	1					No Data
North Springwater	30&31				4.5	4.5
Hummel House	9&10	6.6	6.5			13.1
Heart S Ranch	13			9.65	7	16.65
Rockhouse	6&7	11	7.5		Not Read	18.5
Upper Mattie	21	12	7.5		6.5	26
Apache	27	11	10.5		5.5	27
Road Canyon	11&12	10.5	7	6.75	5	29.25
Oak Tree	2&3	12	9.5	7.75	Vandalized	29.25
Lower Mattie	20	12	6	5.5	7	30.5
West Pasture	17&18	8.7	6.55	7.65	5.9	28.8
Five Wire	19	11	6.5	7.25	6	30.75
Fresno	22	13	6.25	6.25	6	31.5
East Davis	15	8.5	7.5	6.75	9	31.75
Runway (Lower North)	8	11	11	6.75	4	32.75
South Springwater	16	11.5	8	9.25		28.75
North Well	4&5	14	12.5	7.5	4.5	38.5
West Davis	14	12	9	8.65	10	39.65

Table 21. Summer precipitation recorded for pastures and key areas from 2001 to 2004 as well as the 4-year cumulative summer total. Pastures with key areas not meeting perennial grass cover objectives (basal cover < 10%) are highlighted.

Location or Pasture	Key Area	6/01-9/01	6/02-9/02	6/03-9/03	6/04-10/04	4-Year Summer Total
Empire Headquarters	1					No Data
North Springwater	30&31				4.5	4.5
Hummel House	9&10	6.6	6.5			13.1
Heart S Ranch	13			9.65	7	16.65
Rockhouse	6&7	11	7.5		Not Read	18.5
Upper Mattie	21	12	7.5		6.5	26
Apache	27	11	10.5		5.5	27
Road Canyon	11&12	10.5	7	6.75	5	29.25
Oak Tree	2&3	12	9.5	7.75	Vandalized	29.25
Lower Mattie	20	12	6	5.5	7	30.5
West Pasture	17&18	8.7	6.55	7.65	5.9	28.8
Five Wire	19	11	6.5	7.25	6	30.75
Fresno	22	13	6.25	6.25	6	31.5
East Davis	15	8.5	7.5	6.75	9	31.75
Runway (Lower North)	8	11	11	6.75	4	32.75
South Springwater	16	11.5	8	9.25		28.75
North Well	4&5	14	12.5	7.5	4.5	38.5
West Davis	14	12	9	8.65	10	39.65

- Establish additional key areas on limy slopes in Apache, Rockhouse and Upper Mattie Canyon pastures and, if possible, on other ecological sites that are under-sampled allotment wide, to assist in the evaluation of livestock grazing and climatic factors in these pastures. This will be addressed through the addition of paired key area plots and exclosures on south-facing slopes.
- Identify the effect of public recreation on the grasslands.
- Identify the effect of public recreation on livestock and wildlife.

The TRT and RRT also identified some refinements that needed to be made to the RMP's resource objectives in order to improve BLM's ability to manage the diverse expression of semidesert grassland on different soil types. These refinements include:

- Define *desired* objectives and thresholds for basal cover of perennial grasses by ecological site that should be maintained or improved.
- Based on soon-to-be-revised ecological site descriptions, refine acceptable similarity index values for Lehmann lovegrass-invaded sites to acknowledge the watershed protection and increased forage that the species provides.

In February, 2004, the TRT selected five sites for additional key areas and adjacent livestock exclosures in Rockhouse, Apache, Upper Mattie and Springwater pastures. The exclosures are sited to avoid the problems associated with the existing ones. That is, they will be located 0.75-1.0 mile from watering points, away from salting areas and livestock trails, and on the same soil type as adjacent unfenced key areas. These key area pairs are located on volcanic hills, clayey hills upland, limy slopes and shallow upland ecological sites. This adds an additional ecological site with key areas appropriate for evaluating livestock effects, increasing the total to 11 out of a possible 15 ecological sites (73%) on the Empire Cienega Allotment (see Appendix A). In addition, the TRT will tackle the identification of biologically important thresholds for basal cover of perennial grasses by ecological site by late spring. Issues concerning public recreation impacts are outside of the purview of this report but are being addressed by the BLM.

Continued success of the adaptive management process for livestock grazing management will require that the field work, summary and interpretation of monitoring data, and presentation to the TRT, RRT and Biological Planning Team for evaluation of the proposed grazing plan be completed over a relatively short time period dictated by the growing season of warm-season perennial grasses. This creates a scheduling challenge that will require careful planning in subsequent years so that all steps are completed in a timely, efficient manner. A timeline was developed to facilitate the adaptive management process for grazing management decisions on the Empire Cienega Allotment for future years (Table 22).

Table 22. Adaptive management timeline for upland monitoring on the Empire Cienega Allotment.

1st week of September - Lessee turns in form that identifies proposed pastures to be used for livestock grazing for fall and spring

3rd and 4th weeks of September and 1st week of October - BLM monitors all cover plots. (If there is not sufficient time to monitor all plots, then plots located in pastures that lessee has proposed to graze will be prioritized and read that year.)

2nd and 3rd weeks of October - Monitoring data is entered into computer and analyzed.

4th week of October - Results of current monitoring are shared with lessee so that the proposed livestock grazing and rotation plan can be evaluated in the context of new monitoring data.

1st week of November - Technical Review Team (TRT) meets to discuss results of current monitoring and proposed grazing plan.

2nd week of November - Range Resource Team (RRT) meets to discuss results of current monitoring, proposed grazing plan, and any recommendations for change brought up by TRT.

3rd week of November - Biological Planning meeting is held and results of current monitoring are discussed along with any recommendations for change identified by TRT or RRT.

IV. LITERATURE CITED

Archer, S., C. Scifres, C.R. Bassham, and R. Maggio. 1988. Autogenic succession in a subtropical savanna: conversion of grassland to thorn woodland.

Archer, S., D.S. Schimel, and E.A. Holland. 1995. Mechanisms of shrubland expansion: land use, climate, or CO_2? Climatic Change 29:91-99.

APA (American Planning Association). 2002. Arizona desert conservation plan wins national award. (www.co.pima.az.us/cmo/sdcp/Awards2.htm)

Bahre, C.J. 1985. Wildfire in southeastern Arizona between 1859 and 1890. Desert Plants 7:190-194.

Bahre, C.J. 1995. Human impacts on the grasslands of southeastern Arizona. In: McClaran, M.P.; Van Devender, T.R., eds. The desert grassland. University of Arizona Press, Tucson AZ: 230-26.

Bailey, R.G. 1995. Descriptions of the ecoregions of the United States. 2nd edition. U.S.D.A. Forest Service Miscellaneous Publication No. 1391. Washington, D.C.

Bailey, R.G. 1998. Ecoregions map of North America: explanatory note. Prepared in Cooperation with The Nature conservancy and the U.S. Geological Survey. U.S.D.A. Forest Service Miscellaneous Publication No. 1548. Washington, D.C.

BLM (Bureau of Land Management). 2002. Proposed Las Cienegas Resource Management Plan and Final Environmental Impact Statement. U.S. Department of Interior, Bureau of Land Management, Arizona Field Office.

BLM (Bureau of Land Management). 2003. Approved Las Cienegas Resource Management Plan and Record of Decision. U.S. Department of Interior, Bureau of Land Management, Arizona Field Office.

Bock, C.E., and J.H. Bock. 1978. Response of birds, small mammals, and vegetation to burning sacaton grasslands in southeastern Arizona. J. of Range Management 31:296-300.

Brown, J.H., T.J. Valone, and C.G. Curtin. 1997. Reorganization of an arid ecosystem in response to recent climate change. Proc. National Academy Sciences 94:9729-9733.

Cable, D.R. 1967. Fire effects on semidesert grasses and shrubs. J. Range Management 20:170-176.

Cox, J.R., and G.B. Ruyle. 1986. Influence of climatic and edaphic factors on the distribution of *Eragrostis lehmanniana* Nees in Arizona, USA. Journal Grassland Society of S. Africa 3(1):25-29.

Dick-Peddie, W.A. 1993. New Mexico vegetation: past, present and future. University of New Mexico Press, Albuquerque, NM.

Elzinga, C.L., D.W. Salzer, J.W. Willoughby. 1998. Measuring and monitoring plant populations. Bureau of Land Management Technical Reference 1730-1.

Glendening, G.E. 1952. Some quantitative data on the increase of mesquite and cactus on a desert grassland range in southern Arizona. Ecology 33:319-328.

Gori, D.F., and C.A.F. Enquist. 2003. An assessment of the spatial extent and condition of grasslands in central and souther Arizona, sowwestern New Mexico and northern Mexico. Report by The Nature Conservancy. 28 pp (www.azconservation.org)

Gori, D., and D. Backer. *In press*. Watershed improvement using prescribed burns as a way to restore aquatic habitat for native fish. In: Connecting mountain islands and desert seas: biodiversity and management of the Madrean Archipelago II and 5th Conference on research and resource management in southwestern deserts. 2004 May 11-15; Tucson AZ. Gen. Tech. Report RM-GTR-

Fromer, P. 2004. Advance draft Pima County multiple species conservation plan. Pima County, AZ.

Hastings, J.R., and R.M. Turner. 1965. The changing mile. University of Arizona Press, Tucson, AZ. 317p.

Hennessey, J.T., R.P. Gibbens, J.M. Tromble, and M. Cardenas. 1983. Vegetation changes from 1935 to 1980 in mesquite dunelands and former grasslands of southern New Mexico. Journal of Range Management 36:370-374.

Herrick, J.E., J.W. Van Zee, K.M. Havstad, L.M. Burkett, and W.G. Whitford. Monitoring manual for grassland, shrubland and savanna ecosystems. Volume I. Quick Start. USDA-ARS Jornada Experimental Range, Las Cruces, NM. 33 pp.

Humphrey, R.R. 1958. The desert grassland: a history of vegetational change and an analysis of causes. Bot. Rev. 24:193-253.

Marshall, R.M., D. Turner, A. Gondor, D. Gori, C. Enquist, G. Luna, R. Paredes Aguilar, S. Anderson, S. Schwartz, C. Watts, E. Lopez, and P. Comer. 2004. An ecological analysis of conservation priorities in the Apache Highlands ecoregion. Report by The Nature Conservancy of Arizona, Instituto del Medio Ambiente y el Desarrollo Sustentable del Estado de Sonora, agency and institutional partners. 152 pp. (www.azconservation.org)

Martin, M.S. and D.R. Cable. 1962. Grass production high 14 years after mesquite control. Ariz. Cattlelog 18(12):58-61.

McAuliffe, J.R. 1995. Landscape evolution, soil formation, and Arizona's desert grassland. In McLaren, M.P. and T.R. Van Devender, eds. The desert grassland. The University of Arizona Press, Tucson, AZ:100-129. .

McPherson, G.R. 1995. The role of fire in desert grasslands. In McLaren, M.P. and T.R. Van Devender, eds. The desert grassland. The University of Arizona Press, Tucson, AZ.

McPherson, G.R. 1997. Ecology and management of North American savannas. University of Arizona Press, Tucson, AZ. 208 p.

McPherson, G.R., and J.F. Weltzin. 2000. Disturbance and climate change in the United States/Mexico borderland plant communities: a state-of-the-knowledge review. U.S.D.A. Forest Service General Technical Report RMRS-GTR-50. Rocky Mountain Research and Experiment Station, Fort Collins, CO. 24p.

Norton, G. 2003. U.S. will protect Las Cienegas area'. Guest Editorial, Arizona Daily Star, February 5, 2003.

Pellant, M., P. Shaver, D.A. Pyke, and J.E. Herrick. 2000. Interpreting indicators of rangeland health, version 3. Technical Reference 1734-6. U.S. Department of Interior and U.S. Department of Agriculture.

Reynolds, H.G., and J.W. Bohning. 1956. Effects of burning on desert grass-shrub range in southern Arizona. Ecology 37:769-776.

Ruyle, G.B. No date. Some methods for monitoring rangelands and other natural area vegetation. Extension Report 9043. Division of Range Management, Univ. of Arizona College of Agriculture, Tucson, AZ. 90p.

Schlesinger, W.H., J.F. Reynolds, G.L. Cunningham, L.F. Huenneke, W.M. Jarrell, R.A. Virginia, and W.G. Whitford. 1990. Biological feedbacks in global desertification. Science 247: 1043-1048.

Sundt, P. 2002. The statistical power of rangeland monitoring data. Rangelands 24(2):16-20.

Swetnam, T.W. 1990. Fire history and climate in the southwestern United States. Krammes, J.S., tech. coord. Effects of fire management of southwestern natural resources. U.S.D.A. Forest Service General Technical Report RM-191. Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO. 6-17.

Valone, T.G., and D.A. Kelt. 1999. Fire and grazing in a shrub-invaded arid grassland community: independent or interactive ecological effects? J. of Arid Environments 42:15-28.

Wright, H.A. 1980. The role and use of fire in the semidesert grass-shrub type. USDA Forest Service General Technical Report INT-85. Intermountain Forest and Range Experiment Station, Ogden, UT.

APPENDIX A. MONITORING PROTOCOL REVIEW

PROTOCOL DESCRIPTION

Three monitoring methods for grasslands—dry weight rank, point intercept, and pace frequency—were used on the Empire Cienega Allotment between 1995 and 2003 as part of the Bureau of Land Management's (BLM) original monitoring plan (BLM 2002). These methods provided estimates of plant species composition by weight (dry weight rank), substrate cover in 5 cover classes: bare ground, gravel, rock, litter, and live basal vegetation (point intercept), and density and dispersion of plant species (pace frequency) [Ruyle, no date]. The dry weight rank information was used to generate NRCS's similarity index rating, a score that evaluates overall rangeland condition. While the sampling techniques for each method vary, the sample size and location were similar for each. One hundred points (point intercept) or 100 40 cm x 40 cm quadrats (pace frequency and dry weight rank) were sampled along 2 or 4 parallel transects that were 50 or 25 paces in length, respectively. Transects were located at 30 key areas that were distributed throughout the major pastures and ecological sites on the Empire Cienega Allotment. For a more detailed description of the original sampling protocol see BLM (2002).

To evaluate the efficacy of the BLM's monitoring plan to meet their Resource Management Plan (RMP) objectives, we completed three analyses. The first analysis evaluated which of the monitoring methods/protocols yielded information suitable for determining if management objectives were being met. The second evaluated the stratification of sampling locations necessary to meet RMP objectives, while the third analysis evaluated the statistical power to detect change of each of the monitoring protocols. A detailed discussion of these analyses as well as recommendations for revision of the monitoring plan based on these analyses follows.

PROTOCOL EFFICACY IN ADDRESSING MANAGEMENT OBJECTIVES

Management objectives for the upland vegetation, as stated in the Las Cienegas Resource Management Plan and Record of Decision (BLM 2003), are to:

- Maintain or achieve properly functioning upland condition and a high similarity index (> 50% by weight) to the historic climax plant community present on the site on 80% or more of the ecological sites in the Sonoita Valley by the year 2015.
- Maintain or achieve the following ground cover on 80% or more of the ecological sites in the Sonoita Valley by the year 2015. Within Major Land Resource Areas 41-1 and 41-3, maintain or achieve ground cover in woodland communities in excess of 60% (< 40% exposed soil surface), in grassland communities in excess of 70% (<30% exposed soil surface), and in shrubland communities in excess of 40% (<60% exposed soil surface).
- Provide habitat for breeding and wintering sparrows on loamy bottom ecological sites by maintaining an average of 6-8" grass height, ground cover of live grasses and grass litter > 75%, and less than 10% shrub canopy cover on two-thirds of the loamy bottom swales that are sampled each year.

- Provide habitat components for pronghorn fawning in open grassland and draws (e.g., loamy botttom swales, loamy hills, and limy slope ecological sites within key fawning areas) by maintaining: vegetation cover 10-18” high during the fawning season; the presence of 5 or more species of grasses and shrubs in the vegetation communities; and limiting trees to no more than 5% of the total cover while maintaining trees greater than 12’ tall in the habitat.

Our analyses concern only the first two upland objectives. Monitoring that addresses the habitat objectives for sparrows and pronghorn during the breeding season has been sporadic and not systematic. Future work will focus on the evaluation and, if needed, revision and field-field testing of the monitoring protocol for sparrow habitat; the results will be summarized in later chapters of this report. BLM intends to use the results of the Arizona Game and Fish Department pronghorn study to develop a monitoring protocol for pronghorn habitat.

A comparison of the first two management objectives with information obtained from pace frequency, point intercept, and similarity index rating methods indicated that only the point intercept and similarity index rating methods yielded data pertinent to these objectives (Table 23).

Table 23. Comparison of information obtained from specific monitoring methods with information needed to address management objectives.

Monitoring Protocol	Grassland Variable Estimate	Addresses Management Objective?
Point Cover	Substrate cover including bare ground and litter cover Change in perennial grass cover/composition Increase in exotic grass cover	Yes
Similarity Index	Properly functioning upland condition and percent similarity to historic climax	Yes
Frequency	Combination of density and dispersion of plant species	No

The second analysis evaluated whether or not the stratification of key areas was adequate to meet the RMP upland objectives of “80% or more of the ecological sites in the Sonoita Valley by the year 2015”. Because long-term monitoring data are available only for the Empire Cienega Allotment, our analysis was limited to the ecological sites found there, not the entire Sonoita Valley. Thirteen of the 15, or 87%, of the possible ecological sites had key areas located in them, while 10 of the 15, or 67%, of the ecological sites had key areas that were appropriate for evaluating livestock grazing effects (Table 24). Specifically, there are no key areas located on clayey hills or sandy bottom sub-irrigated ecological sites, while there are also no key areas with the potential to show grazing effects on the limestone hills, limy upland, or sandy bottom ecological sites. However, sandy bottom sub-irrigated sites are being monitored throughout LCNCA using a riparian monitoring protocol (BLM 2002).

Table 24. Ecological sites within the Empire Cienega Allotment and the key areas associated with them. Key areas in bold are those that are not appropriate for evaluating livestock grazing effects. Ecological sites in bold are those sites that either do not have a key area located within them or a key area that is appropriate for evaluating grazing management.

Ecological Site	Key Area
Basalt Hills	23
Clayey Hills	
Limestone Hills	**21, 26**
Limy Slopes	4, 6, 15, 22
Limy Upland	**28**
Loamy Bottom Mesquite	24, 25
Loamy Bottom Sub-irrigated	19
Loamy Bottom Swales	10, 14
Loamy Hills	2, 3, 11, 12
Loamy Upland	1, 13, 16, 17, 18, 30
Sandy Bottom	**20**
Sandy Bottom Sub-irrigated	
Sandy Loam Upland	8, 9, 31
Shallow Upland	5
Volcanic Hills	7, **27**

STATISTICAL POWER TO DETECT CHANGE

The analysis of statistical power to detect change was completed for the pace frequency and point intercept protocols but not for the similarity index protocol due to the complexity of the methodology. In particular, the dry-weight rank method is used to estimate species composition by weight; the observed values are compared to those in NRCS' Ecological Site Descriptions (ESD) and a percent similarity to historic climax vegetation, a measure of range condition, is calculated [e.g., Ecological Site Inventory (ESI) Similarity Index]. Since the dry-weight rank method is a derivative one for measuring composition and since these values are, in turn, compared to values in the ESD's which are currently under revision, it is difficult to design a power analysis to investigate the relationship between sampling intensity and sensitivity to change.

The power analysis for the pace frequency and point intercept protocols is identical since both deal with proportional data: percent frequency and percent cover, respectively. For sake of simplicity, we restrict our discussion to the substrate cover/point-intercept protocol. The goal of the analysis is to determine the sample size needed to detect a given amount of change with a given level of statistical power. There are two key components to doing this. The first component is to identify the acceptable level of error in detecting a change in cover (or plant frequency) between two points in time; the second is to identify a biologically meaningful level of change.

The level of acceptable error refers to the probability of making a false-change (Type I) or a missed-change (Type II) error when analyzing the data. Specifically, a false-change error occurs when the observer concludes that a change occurred but no change has actually happened; the opposite occurs with a missed-change error. For academic endeavors, a 5% probability of making false-change or missed-changed errors is normally deemed acceptable, for monitoring programs a 20% probability is usually recommended (Elzinga et al 1998). For the LCNCA, we decreased the probability of making false- and missed-change errors from a standard monitoring methodology to 10% because of the local, regional, and national importance of the site and BLM's management prescription to implement a flexible and adaptive livestock grazing management strategy for the area.

Determining the level of biologically meaningful change requires an understanding of the management objectives as well as the grassland system being monitored. The bare ground management objective requires that the protocol be sensitive enough to pick up changes that approach and pass the bare ground objective values of 30% and 40% so that pro-active changes in grazing management can be made before the system is severely damaged. Furthermore, in semidesert grasslands, perennial grass basal cover normally ranges between 10% and 30% with sensitive levels at or below 5% cover. The latter is important because when grass cover is < 5%, erosion potential on many ecological sites increases dramatically and grazing rest may not result in vegetation recovery if soil movement and loss is severe following continued disturbance (Hennessey et. al. 1983; P. Warren, pers. comm.). Given this information, we determined that a biologically meaningful level of change was 2-5% when perennial grass basal cover was 5-10%, and 5-10% change when bare ground cover was 20-40%.

Once identified, the acceptable level of error and biologically-meaningful level of change was plugged into the following equation which calculates the necessary sample size for detecting differences between two proportions (Elzinga et al 1998):

$$n = (Z_\alpha + Z_\beta)^2 (p_1q_1 + p_2q_2) / (p_2-p_1)^2$$

where:
n = estimated necessary sample size
Z_α = Z coefficient for the false-change error rate
Z_β = Z coefficient for the missed-change error rate
p_1 = the proportion value for the first sample, expressed as a decimal
$q_1 = (1 - p_1)$
p_2 = the proportion value for the second sample, expressed as a decimal
$q_2 = (1 - p_2)$

Using this equation, the sample number necessary to detect 5%, 10%, and 20% changes in cover with a 10% probability of false- and missed-change errors was determined (Figure 7). Results showed that a 20% change can be detected with 102 points for cover values ranging from 0% to 100 %, a 10% change can be detected with 422 points for cover values ranging from 0% to 100 %, and a 5% change can be detected with 981 points for values ranging from 0% to 20% and 85% to 100%. Comparison of the level of change detectable with 102, 422, and 981 sample points with the desired level of detectable change (e.g., 2-5% for perennial grass basal cover and 5-10% for bare ground cover) indicates that a minimum of 981 sampling points are needed. With only 100 points sampled in the original protocol, sampling effort was insufficient to detect the desired level of change but it could detect a 20% change in cover for cover values ranging between 0% to 30% and 50% to 100%. If a one-tailed statistical test for independence is used, for example, a chi-square or G-test, then a sample size of 1000 will ensure that the desired level of change can be detected with a 5% probability of a false-change error.

The preceding analysis assumes that points along transects are independent and that replication (i.e. sample size) is at the level of the point. If the transect is the unit of replication, then the analysis differs and an estimate of the pooled sample variance between transects $(s)^2$ is required to solve the following equation:

$$MDC = [\sqrt{(s^2/n)}]\,(Z_\alpha + Z_\beta)$$

where MDC is the size of the minimum detectable change, expressed in absolute terms rather than as a percentage, and n, Z_α, and Z_β are as above (Elzinga et al 1998).

Unfortunately, none of the previous monitoring data collected at LCNCA were summarized by transect, nor were the raw data provided, so a plot- or site-specific estimate of $(s)^2$ is impossible. However, Sundt (2002) performed this analysis using point-cover data collected by the Malpai Borderland Group on monitoring plots, each with 10 transects and 100 cover points per transect for a total of 1000 sample points per plot. He assumed a missed- and false-change error of 20%. Using his equation for the best-fit curve for MDC as a function of the initial cover value for all plots combined, some conclusions about MDC are possible. In particular, for initial cover values ranging from 5% to 10%, an absolute change of 2-3% can be detected, and for values ranging from 30% to 40% a change of 6-7% can be detected. These *detectable* changes compare well with the biologically meaningful changes specified for LCNCA for substrate cover including perennial grass cover. Sundt (2002) concludes that 100 or 200 points for estimating cover is inadequate (i.e., sample sizes are too small) for detecting biologically-meaningful changes in rangelands in most situations. Monitoring data collected in 2004 at LCNCA is amenable to the above analysis (see below, Appendix B). Future work will focus on evaluating the statistical power of the recommended protocol using site-specific estimates of the pooled sample variance and assuming that the transect, rather than the point, is the unit of replication.

As indicated above, the first analysis is also applicable to the frequency protocol. However, without specific management goals or objectives for plant species' frequency, it is difficult to evaluate if a sample size of 100 quadrats will be able to detect changes that are biologically meaningful *within the context of the management objectives*. In any case, there was a general consensus among range management specialists queried that there is value in continuing to take this measurement as an estimate of long-term abundance and composition changes. Ruyle (n.d.) recommended 200 quadrats as a good compromise between data needs for statistical rigor and time costs associated with monitoring but indicated 100 quadrats to be a minimum. Furthermore, species of interest should have frequency values between 20% and 80% since the method is relatively

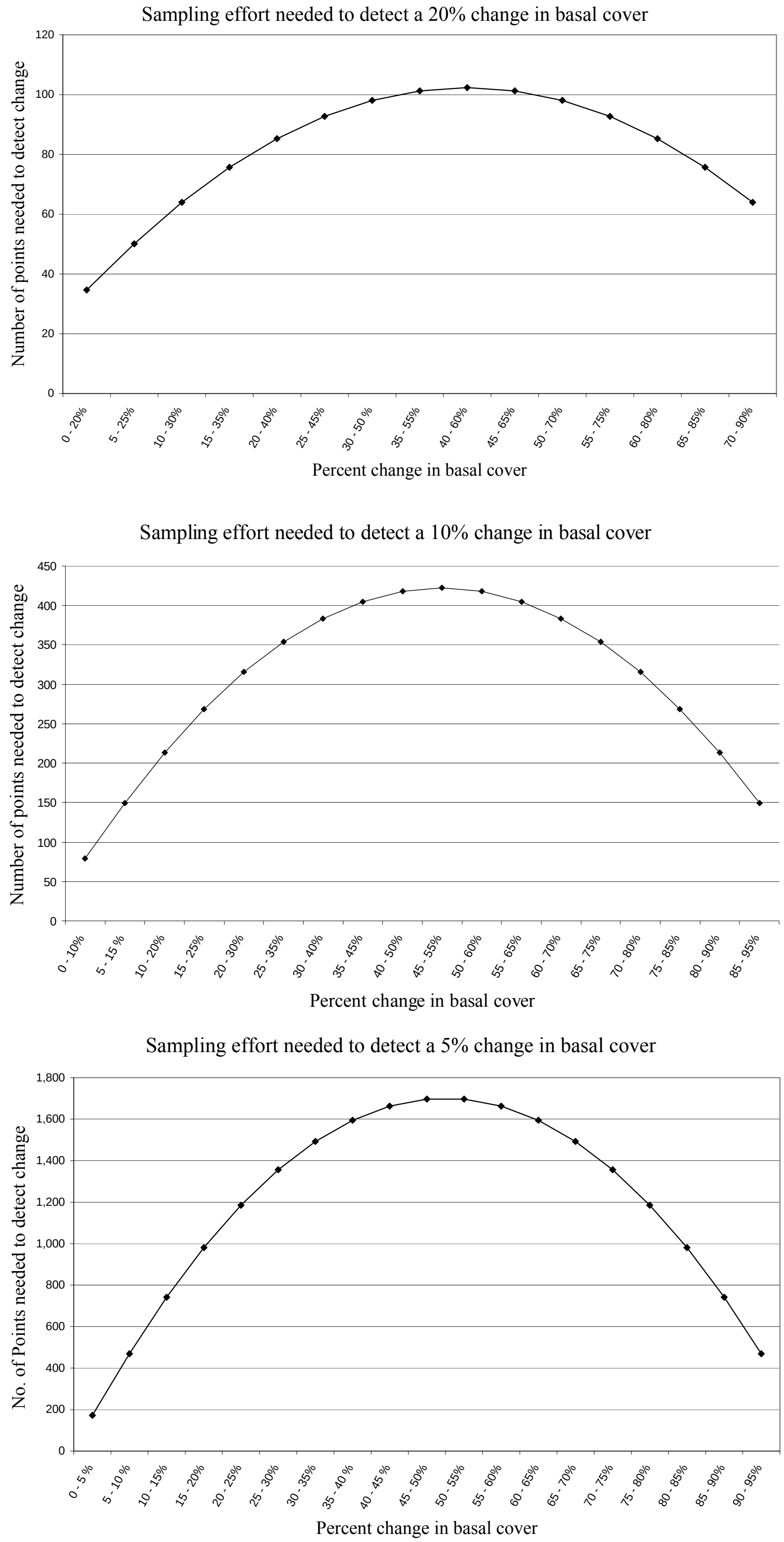


Figure 7. Comparison of the number of sampling points needed to detect a 5%, 10%, and 20% change in basal cover or canopy cover, assuming a 10% probability of false- or missed-change errors.

sensitive to changes in species' density or dispersion within this range whereas frequency values outside of 10% and 90% should only be used to indicate species presence (Ruyle, n.d.).

Given this recommendation, most of the herbaceous species that are being monitored at LCNCA would be eliminated from a quantitative evaluation for change. For example, in 1995, 18 perennial grass species and 19 herbs and annual grasses were recorded from frequency data in Key Area 2. Eleven out of 18 perennial grasses (61%) and 15 out of 19 herbs and annual grasses (79%) had frequency values < 10%. Thus, a lot of effort was expended in identifying and recording these species while sampling when the possibility of detecting change, except for large increases in abundance, is remote. In the absence of specific management goals or objectives for frequency, it is difficult to rationalize this expense of time and resources on data that is of limited use. If frequency sampling is to be continued, we recommend that only perennial grasses be monitored which would reduce time spent monitoring and increase the probability of gathering data that can be used to detect change beyond just species' presence or absence.

Other Considerations

In addition to generating information that can be used to evaluate whether management goals and objectives are being met, a monitoring program should also track changes in system stresses over time. In the case of grassland watersheds at LCNCA, these stresses include declines in perennial grass cover, shrub and tree encroachment, and exotic grass invasion. Information on the extent and intensity of these stresses is important because they may prevent BLM from reaching the management objectives articulated in the RMP and will assist in targeting management strategies and actions to abate these stresses. In any monitoring plan, the need for more information must be balanced with the time and financial costs associated with additional sampling. For this reason, in making recommendations on monitoring protocols, we have tried to build on the original monitoring plan, making the fewest possible changes and augmenting it with complementary monitoring protocols to reduce material and time costs and facilitate comparisons with previously collected data.

Recommended Protocol

Based on the above analyses of monitoring methods, sampling location, sample size, and concerns regarding system stresses, the original monitoring plan was revised and monitoring protocols were field tested in the fall of 2004. The result of this process is a recommended monitoring plan for the uplands on the LCNCA. It is a blend of new and existing protocols with an increased sample size, a revised sampling schedule, and enlarged key area plots that surround and include the original key area transects. For a detailed description of the revised monitoring protocol and key area plot size see Appendix B. The recommended monitoring plan was designed to be carried out by a 4-person crew, with at least 2 persons having the ability to identify all perennial grass and shrub species encountered. The recommended monitoring plan includes point-intercept cover, line-intercept cover, tree density, and dry weight rank (so that a Similarity Index can be calculated) and, if time permits, a frequency sampling protocol with increased sample size for most protocols and a Fall sampling schedule that is either annual, every five years, or every ten years (Table 25). The monitoring plan increases the total monitoring effort for the allotment but this increase occurs only every 5 years when the recommended 5- and 10-year measurements are made (i.e., shrub cover, density, dry weight rank and frequency sampling, if time permits). For annual monitoring, the estimated time to implement the original monitoring plan vs. the recommended (revised) plan is equal, 2 hours per key area for a 4-person crew. It is important to note that while the annual sampling time per plot remains the same, the total number of plots to be monitored will increase (see below).

The sampling times for the 5-year and 10-year measurements (which include the annual measurements) for a 4-person crew are estimated at 3 hours per key area and 4 hours per key area, respectively. If frequency measurements are also made, the estimated time for the 10-year sampling increases to 5.5 or 7 hours per key area depending on whether 100 or 200 quadrats are sampled; the original protocol calls for a sample size of 100 quadrats although BLM's minimum standard for frequency sampling is 200 quadrats.

Table 25. Comparison of time costs associated with the original and revised monitoring plans.

Plan	# of Key Areas Sampled / Year	Information Collected	Sample Size	Frequency of Sampling	Estimated Sampling Time for 4 People
Original	9 to 23	• Substrate Cover • Dry weight Rank • Frequency	• 100 points • 100 quadrats • 100 quadrats	Annual to irregular	2 hours/key area
Revised	24 to 29	• Substrate Cover • Perennial Grass Basal and Canopy Cover	• 1000 points • 1000 points	Annual	2 hours/key area
		• Shrub Canopy Cover	• 500 m of line	Every 5 Years	3 hours/key area, includes annual measurements
		• Mesquite, Juniper, and Oak Density • Dry weight Rank	• Complete count in key area plot • 100 quadrats	Every 10 Years	4 hours/key area, includes annual and 5-year measurements
		• Frequency	• 100-200 quadrats	Every 10 years, time permitting	5.5-7 hours/key area includes annual, 5-year, and above 10-year measurements

Our final recommendation is to increase the number of ecological sites with key areas, if feasible, to facilitate meeting the upland objectives on 80 % of ecological sites on the Empire Cienega Allotment. To do this, the number of ecological sites with key areas appropriate for evaluating livestock grazing effects should increase from 10 to at least 12.

Recommended Monitoring Plan Benefits

Overall the recommended changes to the monitoring plan will increase BLM's ability to practice adaptive management in the semidesert grassland uplands of LCNCA by increasing the precision of the measurements taken and by adding monitoring protocols that address stresses on grasslands and their abatement. The increased ability to detect changes in bare ground, perennial grass and shrub cover, shrub density and plant species' composition over short (annual) and longer time periods (decadal) will allow BLM to determine if management objectives are being met and to assess the overall condition of the upland grassland community.

APPENDIX B: RECOMMENDED MONITORING PLAN FOR UPLAND VEGETATION

MONITORING OBJECTIVE: SUBSTRATE AND CANOPY COVER

Based on the management objectives articulated in the RMP and our knowledge of the ecology and management of semidesert grasslands, we set the following monitoring objective for substrate and canopy cover:

To be able to detect at least a 5% (absolute) change in the basal cover of bare ground and litter, and basal and canopy cover of perennial grasses, expressed in percent, with a statistical power of 90% (missed-change error of 10%) and a false-change error of 10%.

The original monitoring protocol used between 1995 and 2003 employs a point intercept method to measure basal cover in 5 substrate categories: bare ground, gravel, rock, litter, and live (basal) vegetation. The measurements were made every pace (approximately 2.5 ft) along 2 parallel transects (or 4 parallel transects depending on the key area) for a total of 100 point-cover measurements. The start of one of the transects was permanently marked with a metal T-post; its direction presumably varied between years as did the location of the other parallel transect(s). This sampling intensity is inadequate to meet the above monitoring objective; rather a minimum of 1000 points is required (see Appendix A). To accomplish this, plots were set up around the original transects in such a way that the latter were embedded within the former (Figure 8).

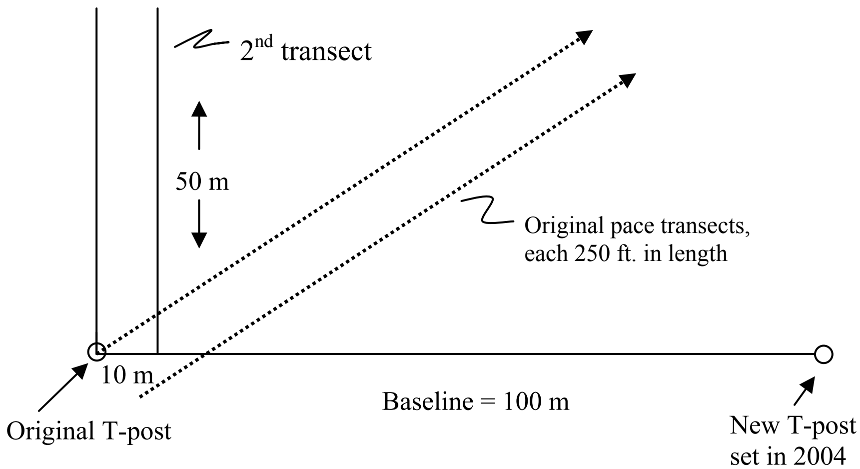
PLOT SIZE

Key area plots are generally 50 m x 100 m in size although plot size is reduced in areas of high topographic diversity to ensure that vegetation in plots was uniform and representative of that along the original transects. In loamy bottoms, plot sizes are larger, if possible, 100 m x 100 m in size. This is done to accommodate the large size of individual sacaton plants and the need for independence of sequential sampling points; the larger plots allowed us to increase the distance between sampling points along transects from 0.5 m to 2 m (see below), thereby satisfying the independence requirement.

SUBSTRATE COVER MEASUREMENTS

Within the plots, ten transects, each 50 m in length (or 100 m in length for the loamy bottoms), are set up and point-intercept measurements are made at 0.5 m (or 2 m) intervals along the transect line. Normally, transects are10 m apart, but are set closer for smaller plots (e.g., 5 to 8 m apart). The substrate categories are expanded from the original protocol and include: bare ground, gravel, rock, litter, perennial grass by species, annual grass, and forbs; no species identifications are made for annual grasses, forbs and shrubs. Canopy (1st hit) and basal (2nd hit) cover hits are recorded separately. Litter is defined as any dead plant material that is detached from the plant; if it is in contact with

Figure 8. Schematic diagram showing the location of a hypothetical key area plot, 50 m x 100 m in size, established in 2004 in relationship to the original monitoring transects, each 250 ft. in length. Point-intercept measurements were made along ten parallel transects, running perpendicular to the baseline and 10 m from each other. Only two of those transects are shown in the diagram. The baseline was permanently marked with T-posts, and included the original T-post (marking the location of the key area) and another set in 2004. In areas where there was considerable topographic variation, plots were smaller to ensure homogeneity of vegetation and ranged from 25 m x 80 m to 40 m x 80 m in size.



the soil surface where the point hits, it is considered basal litter, if not, it is considered canopy litter. Canopy cover of shrubs, grasses and herbs includes all green and dried vegetation that is still attached to the plant. Gravel ranges in size from 0.25 inches to 3 inches in diameter; rock is > 3 inches in diameter.

Tracking cover of perennial grasses by species provides a way to measure compositional changes in the plot at least for the most common species growing there (e.g., abundance > 2% basal or canopy cover) as well as changes in total basal cover of perennial grasses. Since the decline in perennial grass cover is an important stress in grasslands and can result in excessive soil erosion and type conversion from grassland to shrubland, it is a critical variable to measure. In addition, canopy cover estimates provide information on watershed condition beyond what basal cover estimates of bare ground and live (basal) vegetation can provide because grass, forb, or litter canopy can protect bare ground (soil) beneath them from the erosive impacts of raindrops. Canopy cover estimates can also provide additional direction in making grazing management decisions. For example, if bare ground cover is high in a pasture but so is the canopy cover of herbaceous vegetation, light use by livestock may be permitted without compromising the bare ground objective for the pasture.

For canopy cover estimates to provide an unbiased measure of species composition for perennial grasses, measurements must be made at the end of the growing season but before the key area has been grazed. This is so because grazing differentially removes canopy cover from species as a function of their palatability. Thus, the relative abundance of more palatable grasses would be underestimated while that of less palatable ones would be overestimated.

SHRUB COVER AND MESQUITE/JUNIPER/OAK DENSITY

No estimates of shrub cover or density were made in the original protocol. Since this information pertains to an important stress on grassland systems and will be useful in planning, prioritizing and evaluating the success of vegetation management treatments, our proposed protocol calls for measuring shrub cover by species using a line-intercept method. Shrub composition and cover estimates are also needed to determine whether habitat objectives for pronghorn fawning are being met in loamy bottom swales, loamy hills, and limy slopes ecological sites. Measurements occur in the same plots and along the same 10 transects (per plot) used for the substrate cover monitoring (see above; results of power analysis forthcoming). Gaps in the shrub canopy cover of < 10 cm are ignored and the canopy is assumed to be continuous. Since mesquite cover, especially during the initial stage of invasion (when mechanical treatment or prescribed burning is most effective) is low, the number of mesquites in plots will also be counted, recording the number of individuals < 1m and > 1m in height.

Using the equation referenced in Appendix A, the shrub cover data collected in 2004 will allow us to determine the minimum detectable change in canopy cover with 10 transects, assuming a missed- and false-change error of 10%. The Malpai Borderlands Group and BLM-TNC at the Muleshoe Ranch use a similar protocol and sample size for estimating shrub cover and, in both cases have been able to detect changes in shrub cover of 5-10% between two sampling periods.

PHOTOPOINTS

Every time a key area is monitored, 3 photopoints are taken as an accompaniment to the quantitative data. Photopoints are taken several paces behind permanent T-post: (1) along the baseline; (2) along the 1st transect line; and (3) at a 45^{o} angle across the plot.

FREQUENCY OF SAMPLING

Basal and canopy cover measurements of substrate cover should be made on plots annually and accompanied by photopoints (Table 25); shrub cover and mesquite density measurements should be made on plots every 5- and 10 years, respectively.

VEGETATION COMPOSITION—SIMILARITY TO HISTORIC CLIMAX VEGETATION

In the original protocol, the dry-weight rank method was used to determine vegetation composition by weight; these values are compared to values identified in the Ecological Site Description (ESD) and percent similarity to historic climax vegetation, a measure of range condition, is calculated [e.g., Ecological Site Inventory (ESI) Similarity Index].

Since the dry-weight rank method is a derivative one for measuring composition and since these values are, in turn, compared to values in the ESD's which are undergoing revision, it is difficult to design a power analysis to detect the relationship between sampling intensity and sensitivity to change. For this reason, we recommend continuing the original protocol, that is sampling 100 quadrats (40 cm x 40 cm in size) along 2 parallel transects, 50 paces (measurements) per transect. Plots should be re-sampled every 10 years. The reason that we recommend monitoring at this frequency is that (1) often (but not always) changes in range condition often occur over longer, decadal time periods, and therefore do not require or warrant more frequent monitoring and (2) components of range condition that are incorporated in the Similarity Index are already being estimated from substrate and shrub cover sampling.

PLANT SPECIES' DENSITY AND/OR DISPERSION—PACE FREQUENCY SAMPLING

In the original protocol, the frequency of plant species' occurrence in quadrats in each of the monitoring sites (key areas) was determined using a Pace Frequency sampling method. Again 100 quadrats (40 cm x 40 cm) were sampled along 2 parallel transects, each 50 paces in length, or along 4 parallel transects, each 25 paces in length, depending on the key area. Our power analyses indicate that the minimum detectable change at this sampling intensity is 20% (assuming Type I and Type II errors of 0.10). Frequency measurements are useful for tracking changes in the density and/or dispersion of species within plots. However, because it is a composite measure, change in a species' frequency between two points in time may result from a change in density, a change in dispersion (but not density), or a change in both. Because of this uncertainty in interpreting the data, frequency sampling is of limited use as an "early warning" system to detect changes in the abundance and cover of perennial grasses or bare ground. However, if one is willing to accept this level of uncertainty, it may be useful in conjunction with substrate cover data for inferring changes in the density of perennial grass species that are uncommon (but not rare) which substrate cover sampling is not particularly sensitive to. Furthermore, frequency values cannot be directly compared for a single species between plots or between species within plots. In addition, frequency data is time-consuming to collect since monitors must typically recognize 30 to 40 plant species per key area and, with a 40 cm x 40 cm quadrat frame, most herbaceous species are too rare to detect a quantitative (statistically significant) change in frequency. In contrast to cover estimates, frequency data do not provide a direct measure of soil stability, erosion potential, or watershed condition. For these reasons, frequency measurements are rarely used in range management research.

Because there are no objectives in the RMP that deal directly with plant species' density or dispersion and because frequency data is difficult to interpret in the absence of accompanying cover data, we recommend continuing the monitoring as before (100 quadrats) or increasing the sample effort to 200 quadrats, BLM's minimum standard for frequency sampling, at 10 year intervals *only if cover, stubble height and site condition (ESI Similarity Index) monitoring is completed.* [Stubble height measurements address the upland management objective for breeding and wintering sparrows and pronghorn antelope fawning; future work will focus on evaluating monitoring protocols to estimate this variable.]

<u>APPLICATION BY OTHERS</u>

Sundt (2002; pers. comm.) concluded that 1000 points, distributed along 10 transects in 90 m x 90 m plots was adequate to detect a biologically meaningful change in substrate and perennial grass cover for key areas located on the Gray Ranch, in the Peloncillo Mountains and in the San Bernardino Valley. His recommendations were adopted by the Malpai Borderland Group (MBG) and applied to over 200 key area plots that the MBG is using to track changes in substrate and shrub cover and to assess livestock grazing effects, fire effects, and grassland recovery following drought (and grazing rest). In fact, our recommended protocol for substrate cover is the same as that used by MBG but to accommodate the large number of plots, they have staggered their measurement of key areas. On the Gray Ranch, key areas are sampled every 5-years unless there is a major disturbance after which the plot is sampled annually for the next five years. At other MBG sites, key areas have been sampled every 3 years. After 10 years of monitoring, MBG has re-evaluated their program and decided that they needed a subset of approximately 20 key area plots *with adjacent exclosures and rain gauges* that would be monitored annually in order to improve the resolution of their monitoring data.

The Conservancy is using a similar protocol to the one recommended for LCNCA (for substrate, shrub cover) to evaluate the effect of prescribed burning on watershed condition on the Muleshoe Ranch Cooperative Management Area, except that 750 cover points are collected on 15 transects in each key area. Shrub cover is estimated using a line-intercept method on 5 transects. The reduced sampling intensity is justified because the Muleshoe has been rested from livestock grazing for 20 years and is currently ungrazed. The frequency of monitoring is set by the prescribed burn schedule: burn and control plots are monitored 1 growing-season before a burn, 2 growing seasons after a burn and 5 years after a burn. A similar protocol for estimating substrate and shrub cover has also been implemented at TNC's Aravaipa Canyon Preserve

The same monitoring method for substrate cover (1000 cover points measured along 10 parallel transects) is also being applied at:

- San Rafael Ranch
- San Antonia Ranch; and
- San Rafael Ranch State Park (Arizona State Parks)

Finally, scientists at USDA-ARS Jornada Experimental Range recommend using point-intercept measurements along transects to estimate substrate cover as 1 of 4 core monitoring methods; the others core methods are gap intercept, photopoints and a soil stability test (Herrick et al. 2005).

VITAL SIGNS AND NPS' INVENTORY AND MONITORING PROGRAM

To generate reliable data needed to manage and maintain critical resources, the National Park Service (NPS) established a nationwide Vital Signs Inventory and Monitoring Program composed of 32 park networks grouped by proximity and ecological similarity. The Sonoran Desert Network (SDN) includes national parks and monuments in the Sonoran Desert and the higher-elevation "sky island" region to the east where LCNCA is located. SDN is partnering with professionals from universities, agencies and non-profit organizations to expand its park ecological monitoring framework to other sites in the region and to assist with the development of statistically robust monitoring protocols. Thus, we are collaborating with SDN in our efforts to review, make recommendations, and assist BLM with the development of an ecosystem monitoring plan for LCNCA with the idea that the monitoring parameters and protocols we develop can be broadly applied to other sites (including NPS sites) that share ecosystems, target species, and stresses with LCNCA.

The monitoring plan described above for the grassland-watershed at LCNCA addresses a number of *vital signs* (and monitoring parameters) identified by SDN for their parks and monuments regionally. These include: *soil cover* (percent cover of soil surface by ground cover type); *exotic plants—status and trends* (percent canopy and basal cover of Lehmann lovegrass, cover/abundance relative to native flora); and *vegetation community structure and demography* (percent canopy and basal cover of shrubs, grasses and herbs, density of key shrubs in 2 size classes). Together, these vital signs address soil function and dynamics, spread and dominance of invasive /exotic plants, and the biological integrity of desert (grassland) communities.