Final Report, Joint Fire Sciences Program 01-3-3-20.

Project Title: Experimental studies of the role of fire in restoring and maintaining arid grasslands.

Project Location: Gray Ranch, Southwestern New Mexico.

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Project Background: Historical writings, old photographs and paintings and paleo-ecological studies document changes typical of desertification (e.g. increases in woody vegetation and declines in grasses) throughout the arid regions of the southwest within the past 150 years (Hastings and Turner 1965, Cook and Reeves 1976, Grover and Music 1990, Bahre 1991). Data from long-term ecological studies and remote sensing indicate that these changes have continued, and in some cases accelerated, in the last 25 years (Swetnam and Betancourt 1998, Curtin and Brown 2001). These increases in woody vegetation have two fundamental implications for fire dynamics in the southwest; 1) they can either increase fuel availability and fire intensity, or 2) they can reduce fine fuels and retard fire spread. Either scenario seriously disrupts the historical fire regime. While fire and grazing have been a long-term concern for land managers in the southwest (Leopold 1924), and some good comparative studies exist (Ffolliot et al. 1996, Tellman et al. 1998), there are no replicated, long-term landscape studies of fire and its interaction with herbivory (Curtin and Brown 2001). Land managers have little guidance when it comes to understanding the ecological implications of suppressing, or managing for fire, in arid grasslands. Our study provides perhaps the first opportunity to document in an experimental setting the effects of fire and its interaction with grazing while offering land managers the experience of directly observing the relative effects of fire in grazed, and ungrazed landscapes

Objectives: The objective of this study is to determine the effects of fire and grazing (native herbivore and livestock), both singularly and in combination, on the structure and composition of arid grasslands. The goal of generating this information is three fold. First, to document the effect of fire and the interaction of fire with herbivory in arid grasslands and to disseminate this information through peer-reviewed articles, book chapters, and conference proceedings. Second, to serve as one piece in an integrated research program that guides conservationists and land managers in sustaining the ecological health of borderlands ecosystems. Third, to provide a demonstration site where public and private land managers can come and observe the relative effects of these processes on arid grasslands.

Methods: Upper elevation Chihuahuan Desert grasslands are considered one of the most biologically diverse and most imperiled grasslands in the world (Dinerstein et al. 2000). Within the Chihuahuan desert fire and grazing are regular and frequent disturbances that have a profound influence on structuring these grassland ecosystems. The effects of both are inextricably linked and it is not appropriate to consider the effects of one without considering its implications for the other. Because fire and grazing are scale-dependent processes, studies that examine the effects of these processes at small scales are not likely to accurately reflect the impacts of these disturbances at their realistic and appropriate scales. Our 8,876 acre fire research site on the Gray Ranch in southwestern New Mexico provides a rare opportunity to conduct controlled, replicated experiments on the effects of fire, and its interaction with grazing, at scales consistent with landscape scale processes. A study of this magnitude is also an unprecedented opportunity to provide a demonstration site at which land managers can view the effects of fire and its interaction with grazing in a context relevant for making land management decisions.

The basic tenant of the Gray Ranch fire/herbivory studies are to determine what is the minimum scale at which the interaction of the major variables affecting grassland plant and animal species can be studied. This results in what we believe to be a true landscape approach consisting of studies organized around a hierarchy of scales. Given our basic question we believe the use of four 2,200 acre (916 ha.) sub-pastures, each containing a 1 x 1 km square study block with four

200 x 200 m plots within each block, is an appropriate scale at which to conduct our study. Each block is large enough to apply experimental treatments at an appropriate landscape scale, yet small enough to serve as like replicates without losing homogeneity while maintaining enough separation between vertebrate population samples to have true replication. By conducting our study on private lands we have the flexibility to manipulate the landscape unavailable if we had placed the study on federal lands.

McKinney Flats Research Area

Gray Ranch
Hidalgo Co.,
New Mexico

8,876 acres

Blue = Grazed Plots
Striped = Fenced Grazing Exclosure

Study Area: Our study site is located on the 740 square mile Gray (Diamond A) Ranch managed by the Animas Foundation. The Animas Foundation has set aside the 8,876 acre McKinney Flats pasture as a research area. Ungrazed since 1991, the McKinney Flats pasture is located at an elevation of 1650 m. It contains a gradient from Plains-Great Basin grasslands (Bouteloua association), to semidesert grasslands (Bouteloua-Hilaria-Sporobolus association), to Chihuahuan Desert grassland/shrubland (Prosposis association).

Experimental Design: The fundamental underpinning of our research design was the need for independent replication of study plots (Hurlbert 1984, Hairston 1989). This means that there must be a minimum of four replicates of each treatment, and each treatment must, while being comparable to other in biotic and abiotic components, be independent of the others. Statistical analysis can be conducted through ANOVA with each study block and plot an independent replicate, or via regression using a split-plot design.

Initially we had intended to place our grazing treatments in an ungrazed matrix. Yet, we realized that the necessary scaling of this system would result in high intensity, short duration grazing which would not be representative of regional range management practices. Instead we have gone to a four pasture, rest rotation system that is more representative of progressive range management in the region. Each pasture serves as an independent grazing replicate. The solid lines represent pasture boundaries. Burns are conducted in the context of each sub-pasture to attain replication of fire treatments. Within each of the pastures 1 x 1 km. study areas were established. In addition to the proximity to other plots, other constraints on plot placement were the selection of comparable soil and vegetation zones, topography, and distance to a water sources (to avoid this confounding variable we determine that the plots should be at least 1 km from permanent water).

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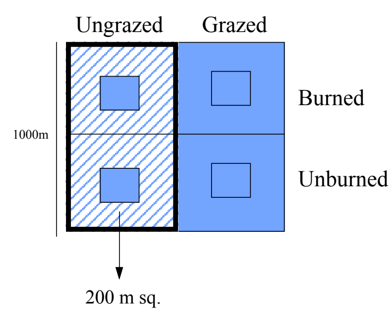
McKinney Flats Fire/Herbivory Studies
Experimental Design



Within each block are four treatment plots: 1) grazed-unburned, 2) grazed-burned, 3) ungrazed-unburned, and 4) ungrazed-burned. Each of these 200 x 200 meter treatment plots were placed as close as possible to the center of the 500 x 500 m blocks to reduce edge effects and maximize distance between samples within each study area. Each stake on every plot has an aluminum tag listing it's location to insure that data locations are properly designated.

Vegetation Monitoring (Primary Production): Our sampling protocol entails using 40 x 40 cm. quadrates set at two meter intervals along ten 150 meter sampling lines. Plot and block locations are GPS'ed and mapped to assure they can be found, even if stakes are removed. This information is filed at Arid Lands Project offices and Animas

Foundation headquarters at the Ranch. Relative frequency data is obtained for each 150m transect by using a series of 75 quadrates systematically placed at 2m intervals along the transect. Relative cover data is obtained by using the four corners of each frequency quadrate as one point-intercept data point resulting in 300 points per transect and 3000 points per 150 x 150 m plot. These plots are sampled following the summer growing season each year.

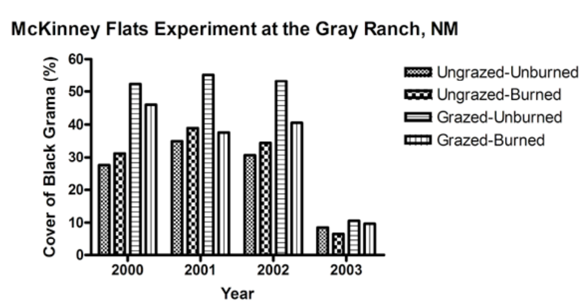
Soil Analysis: In 2003 the preliminary soil analysis will be completed. This project is part of the graduate thesis of Mike Duniway from New Mexico State University and the project is being overseen by Dr. Jeff Herrick of the Jornada. The soil analysis is invaluable in placeing the patterns we see on McKinney Flats within a landscape context. Objectives were to: (1) identify the soil series in each of the research measurement plots (16 fire/grazing interaction + 4 prairie dog + 40 36x36 plots), (2) Generate information that can be used to enhance soil survey interpretation in order to guide both the design of future studies, and the interpretation of the results of these studies in a landscape context. In these studies soil mini-pits and/or auger holes were excavated near the center for each research measurement plot. The soil at each pit was classified based on field characteristics. Soil surface texture was verified in the laboratory (hydrometer method for silt and clay; sieving for sand). Additional pits or auger holes were excavated at any plot within which the soil surface, vegetation or topography indicate that more than one soil series may cover at least 10% of the area. Pits and auger holes were located to minimize impacts on other measurements, and both pits and holes will be re-filled. GPS coordinates were recorded for all sampling points.

Small Mammals (Primary Consumers): Three times a year Sherman traps are placed one meter to the east of the base of the orange 7/16 inch fiberglass stakes located at 30 m. intervals along the five 150 meter transects. This sampling coincides with the lizard sampling to more efficiently use resources and to make lizards and rodents as comparable as possible. In addition some of the smaller species that are not often collected in the Sherman traps, fall into the lizard pitfall traps, increasing the extent of our data. We have found that to ensure the traps are all picked-up by the heat of the day, that only one-half of the site will be trapped at a time (240 traps per night). The duration of trapping is three days in each location. Due to relatively high mammal densities and diversities on the site (roughly 12 species on the site at a given time and two to fifteen captures per 200 x 200 m sampling area), this approach is proving effective at documenting small mammal species composition. Base-line data was collected once a year from 1998 to 2000. Following completion of initial grazing treatments in 2002, we will go to three small mammal trapping sessions each year conducted in conjunction with the summer reptile censuses. After capture species, sex, weight, body and tail length, and hind foot length are measured.

Reptiles/Amphibians (Secondary Consumers): In order to facilitate direct comparison between lizard and mammal populations, we have elected to place pit-fall traps along the same mammal trap lines one meter west of the stakes used for small mammal sampling. Pit-fall traps are censused three times yearly for three days each (totalfield time is 9 days to allow for lizard processing and data collection). These periods include the late spring, after adults emerge and become active (early May), in early summer before the hot dry periods prior to the monsoon (early June), and in late July/early August after the monsoon (when heat and drought sensitive species are likely to be active). After capture the following data on lizards is taken: species, weight, sex, Snout-vent length, tail length and condition, and morphometric measurements to analyze changes in body size. All animals are individually marked through a system of toe clips. Data sheets and information on toe clips is available from Arid Lands Project offices or from New Mexico State Herpetologist Charlie Painter.

Results:

Vegetation Response to biotic/abiotic Interactions: Examination of the interaction of climate, fire, and grazing on native bunch grass black grama (Bouteloua eriopoda) illustrates how these factors interact to structure rangelands. During the period of JFSP support the region faced a severe drought with rainfall declining from 203 mm (8.02 in) in 2000, 2004 mm (8.05 in.) in 2001, to 181 mm (7.14 in.) in 2002, and 172 mm (6.81 in.) in 2003. In 2004 and 2005 the rainfall rebounded to at or above pre-drought level. Initial results of the interaction of climate, grazing, fire show that climate is of overwhelming importance accounting for 55% percent of variation in grass cover. While grazing had a statistically significant positive impact on vegetation cover accounting for 10% percent of variation, fire alone did not. Grazing and fire did have a significant interaction, though considerably smaller than grazing alone accounting for 2.6% percent of variation (percent of variation accounted for = 73.7% percent, $R2 = 0.737$, $p < 0.05$). The results illustrate that researchers and land managers cannot consider these variables in isolation, but should consider them within the context of other factors. That single factor studies at best miss much of the dynamics of the system, and can be extremely misleading. For example in the case of the bunch grasses black grama studies from the 1950s and 1960s indicated that black grama declined following fire (Reynolds and Bohning 1956, Cable 1965). Because black grama grasses are frequently the dominant grass in desert grassland this data was considered to be evidence that this species was not fire adapted, and therefore fire was not a part of desert grasslands (McClaran and Van Devender 1995). Yet subsequent analysis of fire data from McKinney Flats and from monitoring plots from other portions of the Gray Ranch indicate that these results are climatically mediated. During wet periods black grama maintains it's population or increases following fire, whereas during drought it did not. This data is now illustrating that fire has a significant role in maintaining Chihuahua desert grasslands. Illustrating the importance of taking a long-term perspective that factors in environmental variation into the experimental design.



Climate, represented by the yearly variation in results, overwhelms the other key variables including fire and grazing. Yet interactions between variables are frequently considerably more important that the effects of the variables by themselves. The interaction of fire and grazing consistently resulted in greater Black grama cover than any of the variables in isolation. Thresholds and timing are also important. Though the rainfall in 2003 was only 9 mm lower than 2002 the grass cover collapses across all plots.

Role of cattle in desert grasslands: For more than a century conservationists, land managers, and scientists have debated the role of livestock grazing in the degradation of rangelands (Powell 1878, Leopold 1924,USDA 1936, National Research Council 1994, Laycock 1994, Donahue 1999, Curtin et al. 2002, Knight et al. 2002). This debate has peeked in recent years as conservationists and researchers increasingly view ranching and the associated livestock grazing as either a crucial conservation strategy (Starrs 1998, Knight et al. 2002, Maestas et al. 2002), or a major threat (Fleischner 1994, Donahue 1999, Wuerthner and Matheson 2002). While it is impossible to after the fact tease-out the precise effects of a century of grazing, or how the introduction of cattle may have altered the land at the time of European settlement. Landscape level studies can provide important insights into the current effects of livestock. The fundamental hypothesis tested in the coarse of recent analysis of data from McKinney Flats asks: Do cattle reduce the abundance and diversity of key taxa in a desert grassland? Acceptance of the hypothesis would be the result of demonstrably lower biomass and diversity, rejection of the hypothesis would be the result of no effect or demonstrably higher biomass and diversity following reintroduction of cattle.

Grazing studies typically consist of removing cattle from a grazed landscape, comparing the difference between grazed and ungrazed plots, and calling the difference the grazing effect. Because the control is grazing, and the treatment is removal of grazing, in reality grazing exclosure studies are not of grazing, but resilience and rest (Curtin 2002b). Release from disturbance provides important insights into the role of grazing in ecological systems, and the potential of a given landscape to recover following grazing. Yet should not be confused with the actual real-time interactions of herbivores with their environment. Because grazing consists of dynamic interactions with other organisms (such as native herbivores) and processes (such as climate and fire) without viewing grazing in the context of other environmental processes much of the intrinsic function and dynamics of the system are missed (Walker 1988, Frank et al. 1998, McPherson and Weltzin 2000, Curtin and Brown 2001, Curtin et al. 2002). By placed cattle in an ungrazed matrix, and controlling for other disturbance agents, the study design used on McKinney Flats provides important insights into the role of grazing in structuring grassland ecosystems.

Initial data on vegetation and vertebrates indicate that response to the reintroduction of cattle to an arid/semi-arid grassland is neutral or positive. A significant difference in the vegetation biomass in grazed and ungrazed portions of the research area ($P = 0.0001$) existed with mean biomass per 0.40 m2 quadrate 41.6 (SD = 28.6) and 61.9 (SD = 37.6) gms in grazed and ungrazed plots, respectively. These recorded differences are conservative because fall rains caused some vegetative regrowth prior to sampling. Following a season of rest from livestock the mean biomass of grazed (30.5 gms., SD = 19.9) and ungrazed (29.9 gms., SD = 1.4) plots were not significantly different ($P = 0.77$). Vegetation richness was not significantly different between grazed and ungrazed plots in 1999 and 2000 prior to livestock reintroduction ($P = 0.69$ and 0.18, respectively), was significantly higher on grazed plots in 2001 following reintroduction ($P = 0.03$), and returned to non-significant levels in 2002 after a season of rest ($P = 0.84$). Climatic factors correlate with greater change than grazing effects with species number in 1999 prior to the drought in the low 30s, whereas by 2002 species number had dropped by a third to the low 20s (and during 2001 were in the mid-teens). Increases in species number on grazed plots were not the result of colonization of exotic species for no detectable shift in species composition occurred during, or following, implementation of the grazing treatments. Small mammal biomass was not significantly different between plots in 1999 and 2000 prior to livestock reintroduction ($P = 0.34$), yet was significantly higher on grazed plots in 2002 following reintroduction ($P = 0.01$). Small mammal richness (species number) was also not significantly different prior to livestock reintroduction ($P = 0.61$), but was significantly higher on treatment plots following reintroduction ($P = 0.02$). Mammal biomass increased during the sampling period presumably is association with the drought, while diversity declined ($P < 0.05$). Response to grazing by lizards was non-significant with biomass 341.8 gms (SD = 204) in grazed, and 408.8 (SD = 262) in ungrazed treatments ($P = 0.78$). Species richness per plot averaged 5. 2 (SD = 1.3) in grazed and 4.6 (SD = 0.9) in ungrazed treatments($P = 0.32$).

Deliverables:

Yearly Reports to the Rocky Mountain Research Station and Collaborators and peer reviewed publications.

Yearly Field Site Tours to Collaborators, Agency Personnel, Local Groups, National Groups, and numerous others numbering more than a dozen a year.

The project and its results were featured in a number of books, newspaper articles, and films including The New York Times and specials on Public Television.

The Mckinney Flats Project due to its large scale and experimental nature has turned out to be as much as social as a biological experiment. Several peer reviewed papers and book chapters were completed not just on the role of fire and its interactions with grazing, but also the process of developing collaborative science and stewardship.

Due to the inability to burn due to the drought, analysis has focused on the interactions of grazers and climatic effects. A number of papers in review or in preparation directly draw on this data.

Peer Reviewed Publications Supported All or In Part by JSFP:

Brown, J. H., C. G. Curtin, and R. W. Braithwaite. 2003. Management of the semi-natural matrix. In How Landscapes Change: Human Disturbance and Ecosystem Fragmentation in the Americas. P. G. A. Bradshaw and P. A. Marquet, Eds. Springer-Verlag, Heidelberg, Germany. Pp. 328–342.

Curtin, C. 2003. Prairie dogs, cattle, and conventional wisdom. The New Ranch at Work: Proceedings of a Conference. The Quivira Coalition, Santa Fe, New Mexico, USA. Pp. 87– 92.

Curtin, C. G. 2003. Fire as a landscape restoration and management tool in the Malpai borderlands. 1st. National Fire Congress. Pages 79 – 87 in K. E.. M. Galley, R. C. Klinger, and N. G. Sugihara. Proceedings of Fire Congress 2000: The First National Congress on Fire Ecology, Prevention, and Management Proceedings, Tall Timbers Misc. Publication No. 13, Tallahassee, Fl.

Curtin, C. G. 2004. Complexities and Methods of Measuring Environmental Outcomes Pp. 231 – 236. In Proceedings from the Conference for Community-Based Collaboratives. National Workshop on Evaluating Methods and Environmental Outcomes of Community Based Collaborative Process. www.cbcrc.org/events.html.

Curtin, C. G. 2005. Linking complexity, conservation, and culture in the Mexico/US. Borderlands. Pp. 235 – 258. In Natural Resources as Community Assets: Lessons from Two Continents. B. Child and M. West Lyman, eds. Publication of the Sand County Foudation and the Aspen Institute.

Curtin, C. G. 2005. Landscape-level impacts of livestock on the diversity of a desert grassland: Preliminary results from long-term studies. In Connecting Mountain Islands and Desert Seas: Biodiversity and Management of the Madrean Archipelago II. Conference Proceedings May 11-15, 2004. G.. J. Gottfried, B. S. Gebow, L. C. Eskew, and C. B. Edminster, Eds. USDA Forest Service Rocky Mountain Research Station RMRS-P-36.

Curtin, C. G. 2006. Ecological implication of prairie dogs in Chihuahuan Desert grasslands: Initial results from long-term studies. Preservation of Desert Grasslands Conference Proceedings USDA Forest Service Proceedings RMRS-P-40.

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Curtin, C. G. 2006. Role of livestock in mitigating climatically-driven vegetation change. Proceedings of the National Academy of Sciences (In Review).

Curtin, C. G. 2006. Of place and space: A century of science in the borderlands. In The Ecology of Place: Contributions of Place-based Research to Ecological Understanding. I. Billick and M. Price, Eds. Columbia University Press (In Review).

Curtin, C. G. Cattle, small mammals, and prairie dogs: Interactions between keystone herbivores in a desert grassland. Conservation Biology (In Review).

Proposed Verses Attained Deliverables:

Though the Mckinney Flats Project during the period of JFSP support yielded numerous insights, the fire-related results as yet have not meet expectations principally due to unforeseen climatic events. From 2001 through early 2004 one of the harshest droughts in more then 50 years (by some estimates the harshest in over 2,000 years) hit the southwest and our research plots leading to the end of fire treatments and the removal of cattle from the project area in the middle of the JFSP funded portion of the study. Though leading to a short-term loss in products for the JFSP, this event in the long-run will yield much more profound insights into the structure and function of desert grasslands. With several years of pre-drought baseline, three years of drought data, and now several years of post-drought data, we now have a much deeper understanding of the interactions of disturbance events in these systems. The lesson again is one that fire does not exist in isolation from climate and other events. The viewing of “average” fire return intervals or “average” fire events in systems as dynamic as those that occur in the southwest is largely meaningless.

Following two years of post-drought recovery this past spring in 2006 there was again enough fine fuels for a proscribed burn. In May 2006 a prescribed fire was completed on all the treatment plots across the entire study site. Cattle will be reintroduced to the project area in the winter of 2007 and the full factorial design will begin again. This is a long-term study with the results becoming of increasing value each year. Therefore the

JFSP funding will continue to yield results well into the future.

Expected Future Returns from JFSP Funding:

The spring 2006 fire, though having considerable fine fuels, occurred during a period of relatively high humidity. This resulted in a patchy burn of approximately 30% of the landscape cover, compared with earlier burns that had 80 - 95% landscape cover. This contrast of different burn coverage is already yielding significant insights into the impacts of fire. The contiguous burn resulted in profound changes in the biota (especially the composition of small mammal populations), whereas the patchy burn appears to augment existing faunal compositions. The preliminary analysis suggests that managers should carefully consider the potential spatial configuration of burns when design prescribed fires.

The 2006 fire, coupled with a return of cattle in the winter of 2007 will allow us to return to our full factorial design. We expect significant results in the coming months and years. As we approach our tenth season the level of resolution is increasing significantly in the project allowing us to attain a better understanding of grasslands. Our current results now under analysis suggest a much greater difference in the function of grasslands and shrublands and highlight the important role fire can play in preventing grasslands from crossing a threshold and become shrublands. The results also highlight the importance of studies focused on native and relatively undisturbed grasslands. In the southwest the majority of studies are conducted on desertified grasslands, with the results extrapolated to grassland ecosystems. Our preliminary analysis of the interaction of grazers and fire suggests these systems are radically different and that the interactions of biotic and abiotic factors are also fundamentally different within these systems. Potentially leading to very different management outcomes. At this point the research on Mckinney Flats is only becoming more important as we attain a longer-term prospective. We plan to continue the research at least another decade with the next fire scheduled for 2009.

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