The Sevilleta LTER Program, managed by the Department of Biology, University of New Mexico, became part of NSF's LTER Program in 1988. At that time, the research theme of the Sevilleta LTER (SEV LTER) was about "Life on the Edge," or the impact of interannual climate drivers, particularly the El Niño Southern Oscillation, on biome transition zones in the southwestern US. Over time, the focus of our LTER research has expanded to embrace a new overarching goal:

> **to understand the causes of biotic transitions at multiple spatial and temporal scales, and the consequences of those transitions for ecosystem structure and function.**

The Sevilleta LTER Project includes research on biotic transitions in grassland, shrubland, woodland and riparian ('bosque') forests. Each of these transitions is governed by changes in one or two key abiotic drivers, among them climate variability, fire, hydrologic variability and herbivores. Expanding the research to multiple types of transitions increases the generality of SEV LTER research as we tackle a series of parallel hypotheses being investigated within each transition zone, while also increasing the scope and relevance of our long-term research program to address state, regional and national issues.

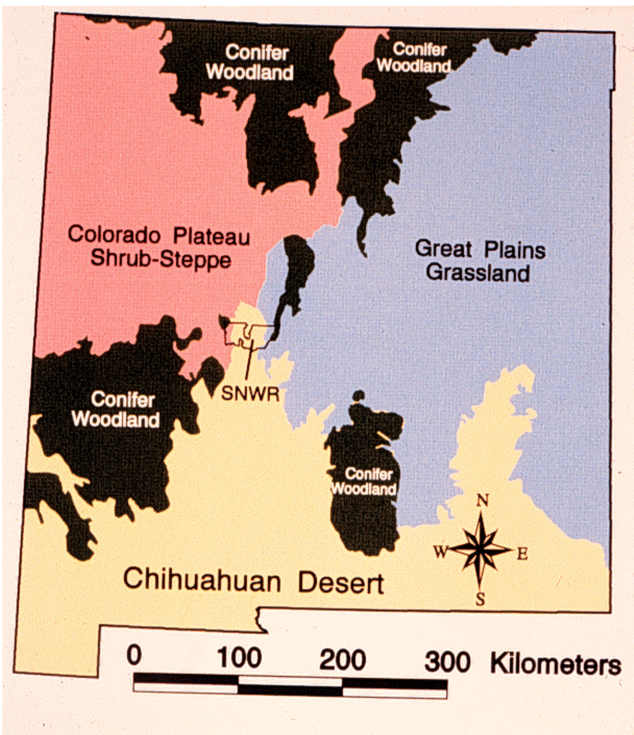


Figure 1. Location of the Sevilleta National Wildlife Refuge, central New Mexico, with respect to the major biomes of the region.

The Sevilleta LTER Project is located about 80 kilometers south of Albuquerque, New Mexico, in and around the Sevilleta National Wildlife Refuge (NWR). The Refuge, which is managed by the US Department of the Interior, Fish and Wildlife Service, and its surroundings, are positioned at the intersection of several major biotic zones: Chihuahuan Desert grassland and shrubland to the south, Great Plains grassland to the north, Piñon-Juniper woodland in the upper elevations of the neighboring mountains, Colorado Plateau shrub-steppe to the west, and riparian vegetation along the middle Rio Grande Valley (Figure 1). Because of the confluence of these major biotic zones, the Sevilleta NWR presents an ideal setting to investigate how climate variability and climate change act together to affect ecosystem dynamics at biotic transition zones. Moreover, the rapid growth and expansion of the City of Albuquerque and its suburbs to the north increasingly will have an impact on ecosystem processes at the Sevilleta, and these urban forces will interact with climatic variation to catalyze change in this aridland region.

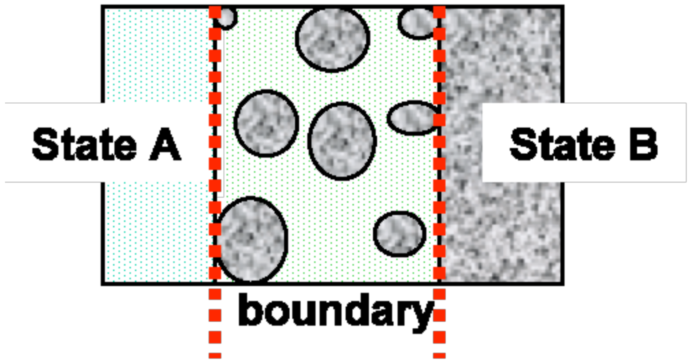


Figure 2. Conceptual model of biotic transitions at multiple spatial scales. A biotic transition consists of two states (A, B) with a boundary between them. The boundary consists of patches from both states that vary in size, type, spatial configuration, and degree of connectivity. The model is applicable across a range of spatial scales, such as individual plants where the boundary consists of root or leaf patches from each plant, assemblages of plants where the boundary consists of patches of individual plants of one species interacting with plants of a different species from an adjacent patch, associations or groups of plant assemblages where each assemblage dominated by one species is a patch, and the boundary consists of these interacting groups of plants, and landscapes consisting of a mosaic of boundaries and states at all smaller scales.

KEY BIOTIC TRANSITIONS

Over the past two decades, one of the key organizing themes in ecology has been patch dynamics. Patch dynamics refers to a change in ecological properties within and among patches through time. A patch is a discrete, bounded area of any spatial scale that differs from its surroundings in its biotic and abiotic structure and composition. The historical emphasis on patch dynamics has led implicitly to the impression that patch change is driven by relatively consistent internal dynamical phenomena. Yet, in some systems, biotic transitions at patch boundaries may be the most dynamic aspects of patches, and processes occurring at boundaries may drive overall patch change. To address this variability and interaction, we developed a new conceptual framework for interactions at patch boundaries from which we derive testable hypotheses for studies of patch dynamics along biotic transitions, a term that we use to include boundaries at all scales (Peters et al. in revision, Figure 2). We are now using this framework to structure our LTER research along a dynamic grassland to shrubland transition zone at the Sevilleta.

Grassland and shrubland transitions. Grassland to shrubland transitions are occurring throughout the southwestern United States in response to a variety of biotic and abiotic drivers. At the SEV LTER, one of the major focuses of our research is the dynamic transition from blue grama (*Bouteloua gracilis*)-dominated grassland to Chihuahuan desert vegetation dominated by black grama (*B. eriopoda*) grassland and creosote (*Larrea tridentata*) shrubland on McKenzie Flats. Essentially, these three species form nearly monodominant patches that represent the end-member states of a complex array of patch types and animal species comprising this relatively abrupt transition zone.

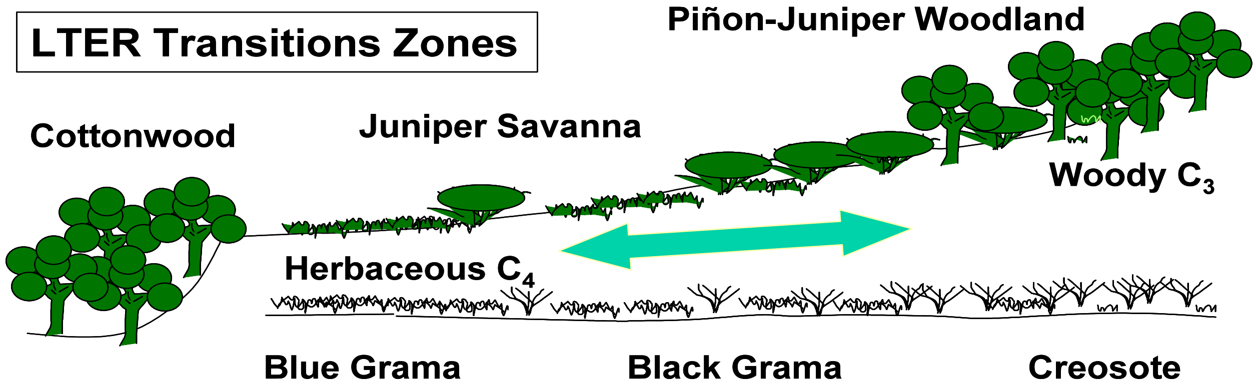


Figure 5. Schematic diagram of upland transitions at the Sevilleta National Wildlife Refuge.

Key drivers of dynamics in this transition zone are grazing, fire and soil water and nutrient availability. On-going experiments are addressing each of these processes (see findings). In addition to pervasive water deficits common in arid regions, the grassland to shrubland transition occurs on soils that are low in total, total nitrogen and nitrogen mineralization rates. Earlier hypotheses suggested that these depauperate soils were the product of historical overgrazing prior to the early 1970's. An alternative hypothesis is that surface soils are young and frequently reworked by wet and dry climatic cycles. Work by two graduate students, Lydia Zeglin (UNM Biology) and Debbie Bryans (UNM Earlth and Planetary Sciences) is addressing these hypotheses. Lydia is studying vegetation greenness and soil fertility in areas that are now grazed, areas that were fenced in 1993 and areas on the SEV that have not been grazed since 1973. Lydia has found that greenness is more a product of precipitation than grazing. However, she has observed that long-term ungrazed area on the on the Sevilleta do have greater soil organic carbon, total nitrogen and C:N ratios than grazed areas all of which supports the grazing hypothesis. Despite these changes in the absence of grazing, soil nutrient levels remain low compared to those found in other grasslands. Debbie Bryans, a soil scientist, is just beginning her detailed studies on soil structure and dynamics across the transition zone from grass to shrub dominance using a series of soil pits around the rainout shelters and in other parts of the transition zone.

Originally, we hypothesized that the dynamics of the grassland to shrubland transition were driven by climate dynamics associated with ENSO events. However, after three such events since the start of the LTER in 1989, there is little evidence that directional change is occurring across this biotic transition zone in response to El Niño or La Niña cycles (Li 2000, 2002). Another mechanism contributing to stasis along this transition zone is population declines in burrow-forming mammals, such as prairie dogs and kangaroo rats. The Dissertation work of Ana Davidson (UNM Biology) shows that disturbances by these animals greatly enhance diversity of plants, total small mammals species richness, birds, ground dwelling arthropods, and herps. Also, these disturbances affect the local distribution and abundance of soil resources (Ayrabe and Kieft 2000). Kangaroo rat mounds are common on the Sevilleta, but prairie dogs are rare. In response to the recent LTER Site Visit, we are planning to incorporate more studies on the impacts of fossorial mammals on Sevilleta grasslands.

Piñon-Juniper woodland transitions. The savanna to woodland transition occurs along an elevation gradient on the north end of the Los Pinos Mountains. This transition zone was part of the original Sevilleta LTER program in 1989, but activities there were reduced over time. This transition begins with savanna characterized by scattered individuals of *Juniperus monosperma* and a dense understory of perennial grasses (primarily *Sporobolis* spp.) to woodland of *J. monosperma* and *Pinus edulis* with a sparse herbaceous understory. In the piñon-juniper woodland, total soil nitrogen and carbon are comparable to levels in other sites across North America, but like in the grassland on McKenzie Flats, nitrogen mineralization rates in PJ soils are extremely low (Zak et al. 1994).

Originally, we hypothesized that the elevational boundary between savanna and woodland was a function of occasional periods of extreme drought. Evidence supporting this hypothesis can be found in the dead juniper carcasses located at the foothills of the Los Pinos Mountains on the east side of the Sevilleta NWR. It is now believed that these long, severe droughts are the product of the PDO, which is hypothesized to have a return interval of 52±11 years (Milne et al, 2003). Currently, the southwestern US is experiencing a severe and prolonged drought, which has many of the characteristics of that experienced in the early 1950's, and a massive die-off of pines and juniper is occurring throughout the region. Bark beetles and fungal pathogens help to increase tree mortality as individuals are weakened by drought. Circumstantial evidence from fertilization experiments at the Sevilleta suggests that piñon mortality rates may be higher in areas of greater resource abundance, thus we hypothesize that mortality of patches of pines may be exacerbated by regional patterns of drought coupled with gradients in atmospheric nitrogen deposition. Overall, this is a significant regional transition that may be part of a long-term cycle from woodland to grassland and back as climate fluctuates on decadal time scales.

To address this question, we have continued to monitor mortality rates in the piñon-juniper woodland, monitored seed and cone production on a set of permanently marked individuals to piñon pine, juniper and oak, and continue to measure root turnover in fertilized and unfertilized plots in the piñon-juniper woodland. Also, we resumed measurements of aboveground net primary production in the herbaceous layer of these forests, and we are in the process of installing tree diameter bands on about 100 individuals to measure rates and changes in tree growth over time.

Riparian zone transitions along the Middle Rio Grande Basin. The Rio Grande, which bisects the State of New Mexico, contains the second largest drainage basin in the southwestern US. Within New Mexico, >60% of the state's population lives along the river and that population is rapidly growing. The Rio Grande provides a considerable amount of surface water for agricultural and other uses and demands on that water are increasing at unprecedented rates. Ecologically, a dramatic biotic transition within the riparian zone ('bosque') is occurring in the Rio Grande Basin as the native forest of cottonwoods is rapidly being replaced by two widely dispersed non-native species, Russian olive and salt cedar. This transition is creating significant ecological challenges related to state and regional water management and policy (Dahm et al. 2002). Although the original Sevilleta LTER research program did not extend into the Middle Rio Grande riparian zone, we feel that doing so now represents a key opportunity to regionalize the Sevilleta LTER and to address important ecological and management issues in the State of New Mexico. In this case, the middle Rio Grande Basin extends from Otowi Bridge near Santa Fe south through Albuquerque and the Sevilleta to

Elephant Butte Reservoir about 150 kilometers south of Albuquerque. Climatically, this region varies from the south where moisture deficits are more severe to the north where there is an increasing period of greater summertime water availability.

Historically, changes in these riparian ecosystems were driven by flood frequency and intensity. Now that the river is highly regulated, floods are rare, the hydrologic regime has been drastically altered, and human-caused fires are common. Since 1990, over 50% of the bosque in the Middle Rio Grande basin has burned. We hypothesize that these changes in disturbance regime will enhance rate of replacement of native species, increase evapotranspiration, and reduce nitrogen retention in the riparian zone.

A fire occurred in mid April 2003 in the bosque just off the Sevilleta in a stand that has been monitored since 1999 as part of a restoration project in the middle Rio Grande. Vegetation is being re-surveyed and soil parameters measured to determine the impact of this fire on forest regeneration. Although some of the cottonwoods were sprouting after the fire, it appears that salt cedar is increasing rapidly at the expense of cottonwood in this stand.

FINDINGS

We have organized our research efforts around three interrelated system components: abiotic drivers, ecosystem processes and biotic responses and feedbacks. In our case, the main abiotic drivers are (1) seasonal, annual and decadal variations in climate, (2) geomorphology, soil texture and depth, and surface hydrology, and (3) season and periodicity of fire. These abiotic drivers affect biogeochemical cycles, particularly nitrogen, phosphorus and carbon, as well as water storage, use and losses. Biotic responses to the coupling of these abiotic drivers and ecosystem processes include patterns and controls on net primary production, and the distribution, abundance, diversity and dynamics of plant and animal populations and communities. Although there is considerable research linking primary production and plant community structure (Waide et al. 1999, Mittelbach et al. 2001), one of the core activities of the Sevilleta LTER has been investigations of fluxes in NPP and their impact on the distribution and abundance of consumers, particularly small mammal populations (Ernst et al. 2001, Friggens 2003). This has direct relevance to human health issues in response to the regional prevalence and potential outbreaks of vector-borne diseases, such as Hanta and Plague (Yates et al 2003).

KEY ABIOTIC DRIVERS: CLIMATE AND WATER

A pervasive limiting resource in these aridland ecosystems is water. In central New Mexico, precipitation inputs vary seasonally, annually and on decadal time scales. In the southwestern US, the amount and timing of seasonal and annual precipitation are influenced by two major climate cycles, the El Niño Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO). ENSO

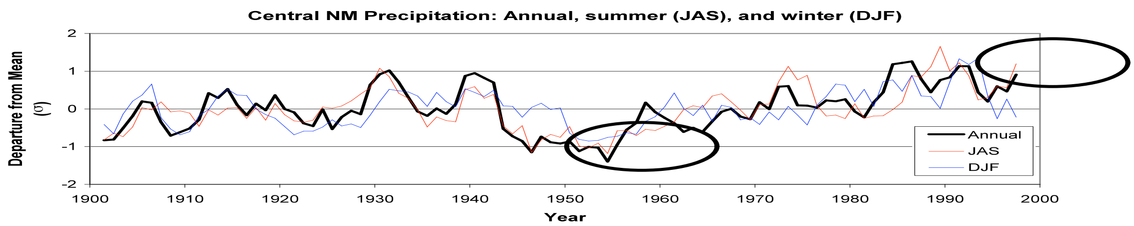
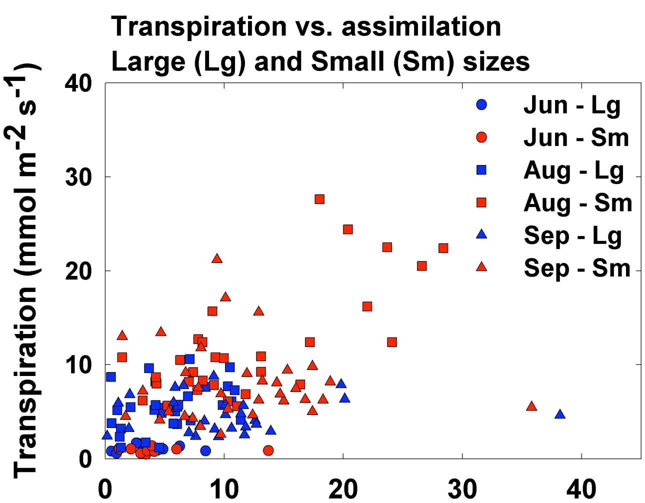


Figure 2. Precipitation patterns for central New Mexico from 1900-1999. Note the regional drought during the 1950's was characterized by low precipitation in both summer and winter seasons.

regulates variability in winter precipitation with high precipitation occurring during El Niño periods, and low precipitation during La Niña periods. ENSO events typically occur every 3-4 years and usually last only through one winter season. More recently it has been suggested that a longer-term climatic event, the Pacific Decadal Oscillation, may have profound effects on regional climate in the southwestern United States (Gutzler et al. 2002). The PDO, which oscillates on approximately 50-year cycles, modulates ENSO events and it may be the cause of periodic, extended, severe droughts in the region (Milne et al. 2003, Fig, 2).

To experimentally investigate the effects of drought on ecosystem processes in these aridland ecosystems, we have nearly completed installation of a series of rainout shelters in grass-, transition and shrub-dominated areas. Rainout shelters were established with funds from SAHRA, an NSF-funded Science and Technology Center at the University of Arizona and SEV LTER. In 2002-2003 growing seasons Pockman and Small (in prep) analyzed the effects of a pulse precipitation event in the transition zone rainout shelters on



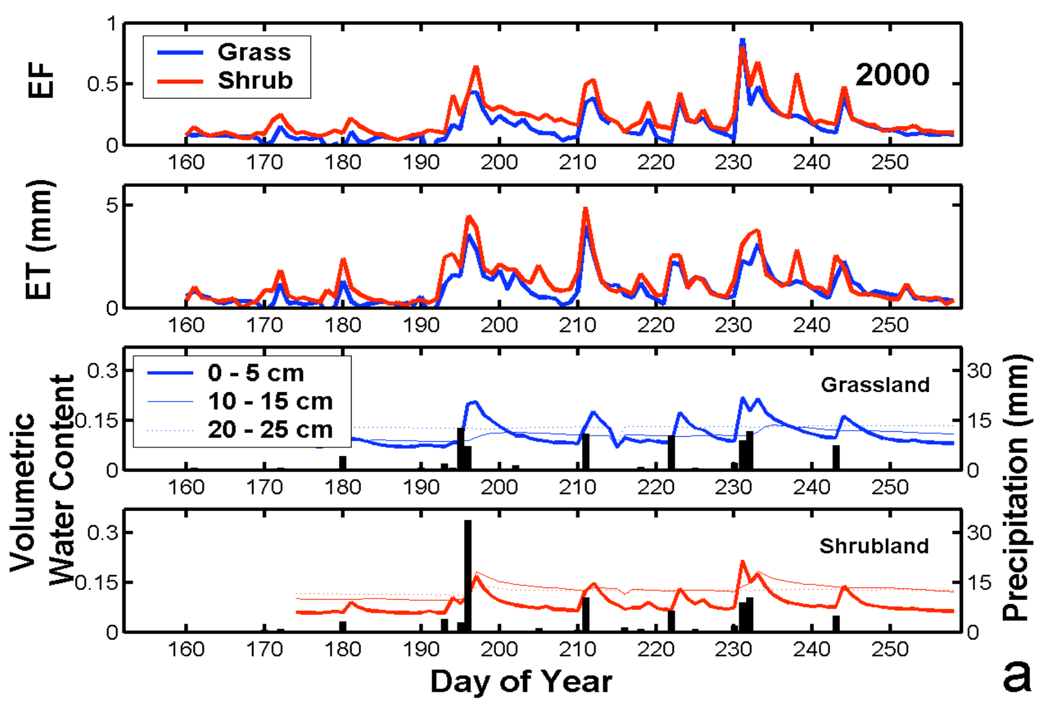
Fgure 1: Growth and water use responses to Summer Monsoon 2002. Small plants were growing faster and using water less conservatively than large plants during the monsoon season of 2002 and Spring 2003, but not during the dry seasons of 2002 and 2003. Though the two sizes did not differ significantly in predawn or midday water potential, in a two-way ANOVA with date and canopy volume as predictors, small plants had significantly higher rates of AM transpiration conductance and photosynthesis, and conductance at midday (a = 0.5). These differences were largest during the summer monsoon of 2002. Small plants responded more to monsoonal moisture than large plants, but their responses to low soil water potentials were very similar to that of large plants.

soil moisture flux and plant responses. These shelters also serve as focal sites for research by Sevilleta graduate students Shirley Kurc (Univ Colorado) and Juliana Medeiros (UNM). Juliana tested two hypotheses on small and large plants in a population of *Larrea tridentata* located

at the Sevilleta LTER in central New Mexico: (1) do small plants grow faster and use water less conservatively than large, and (2) are there differences in the hydraulic constraints on small and large plants. Shoot growth, gas exchange and plant and soil water potentials were measured in the field every six weeks to determine growth rates, water status and water use from April 2002 – August 2003. Measurements of leaf specific conductance determined the ability of the xylem to supply water to the leaves. A model was used to determined the hydraulic constraints on each size based on xylem vulnerability curves and soil texture analysis, which were used to determine the hydraulic properties of the plant xylem and soil. Excavation findings were used to estimate (A_R:A_L) for the model.

Shirley Kurc is conducting her dissertation research on ecosystem level fluxes of water, energy, and carbon cycling in semiarid grassland and shrubland at the Sevilleta. She has collected and analyzed water, energy, and carbon data from two Bowen ratio stations and from two eddy covariance stations (1 of each within grassland and shrubland) which also include soil moisture measurements at several depths. Her research in the summer of 2003 focused on partitioning ET into transpiration and evaporation at the grassland and shrubland in an effort to understand the different controls on ET at these sites. Measurements of evaporation and transpiration were made 3 times a day for a minimum of four days following rainfall input. Evaporation was measured using micro-lysimeters and soil chambers. Transpiration was measured

Figure X. Daily time series of evaporative fraction (midday), ET (daily total), volumetric water content (0-5 cm, 10-15 cm, and 20-25 cm), and precipitation (bars) for summer 2000. Grass is represented by a blue line and shrub by red line. Grassland (blue) and shrubland (red) plots are separate for water content and precipitation.



using leaf gas exchange and whole plant chambers. Midday plant water potential was also measured daily. Data collected this summer are currently being analyzed.

ECOSYSTEM PROCESSES: BIOGEOCHEMISTRY AND DECOMPOSITION

A Major focus of our research in 2003 centered around a planned 6000 ha fire on McKenzie Flats, in part of our intensive study area. The fire occurred from 19-22 June 2003. As noted above, nitrogen pools are very low in these desert grasslands. We hypothesized that fire would increase potential N_{min} rates and increase plant available nitrogen in response to the summer monsoons. To test this hypothesis, soil cores were collected immediately after the fire from burned and unburned areas in fertilized (10gN per m^2) and control treatments on McKenzie Flats. These soils are now being incubated to determine potential N mineralization rates. Soil bridges were installed and measured to determine soil erosion rates following burning. In addition, ion exchange resin bags were buried in burned and unburned areas at the south end of McKenzie Flats. Resin bags were collected at the end of the summer monsoon season and are being analyzed for plant available NO_3, NH_4, and PO_4. Results from these measurements are still being analyzed.

Nitrogen availability is also a function of moisture inputs, plant uptake rates, and time intervals between rainfall events. Soil N availability following drought intervals was determined with long-term Nmin data from the SEV plus new data collected at a grassland area north of Albuquerque. There is a positive association between length of time between precipitation events and N_{min} indicating that nitrogen accumulates during drought intervals (White et al. submitted). Thus the production response to precipitation following drought is not only a function of precipitation, but time since the last rainfall event. This leads to the hypothesis that production responses to equal sized precipitation events may vary depending on the time intervals between events.

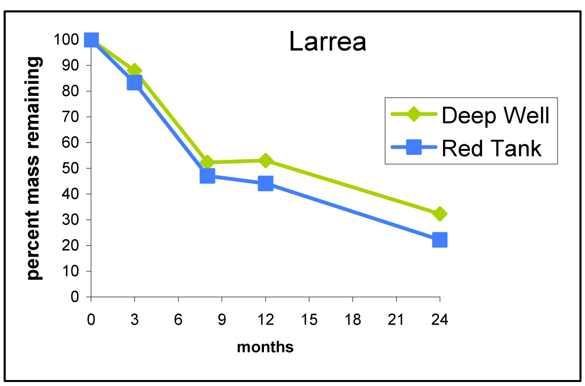
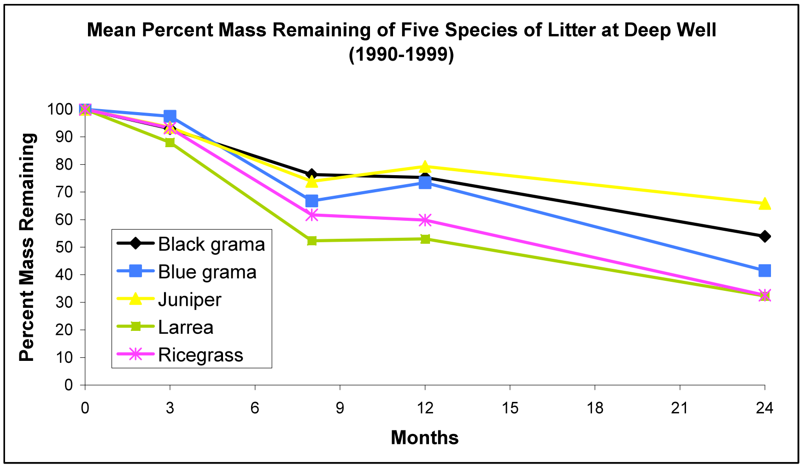


Figure 1. Deep Well and Red Tank are very similar with respect to average annual precipitation and temperature, but Deep Well is dominated by black grama and blue grama , while Red Tank is dominated by juniper and creosote. Differences in the microbial community between sites may result in more rapid decomposition for creosote at Red Tank.

The decade-long Sevilleta Long-Term Plant Litter Decomposition Project (1990-1999) was designed to investigate site, species, litter quality, and climate influences on decomposition. Litter from *Bouteloua eriopoda* (black grama)*, Bouteloua gracilis* (blue grama)*, Oryzopsis hymenoides* (ricegrass)*, Juniperus monosperma* (juniper)*,* and *Larrea tridentata* (creosote) was used in this study. Analyses were done with data from Deep Well, Cerro Montosa, Red Tank, and Rio Salado.

Climate and litter quality variables were largely unrelated to decomposition. Mean percent litter mass remaining after one year was rarely correlated with total annual precipitation, number of rainfall events per year greater than 6 mm, initial litter C:N, initial litter N:P, or average annual temperature for any species at any site.



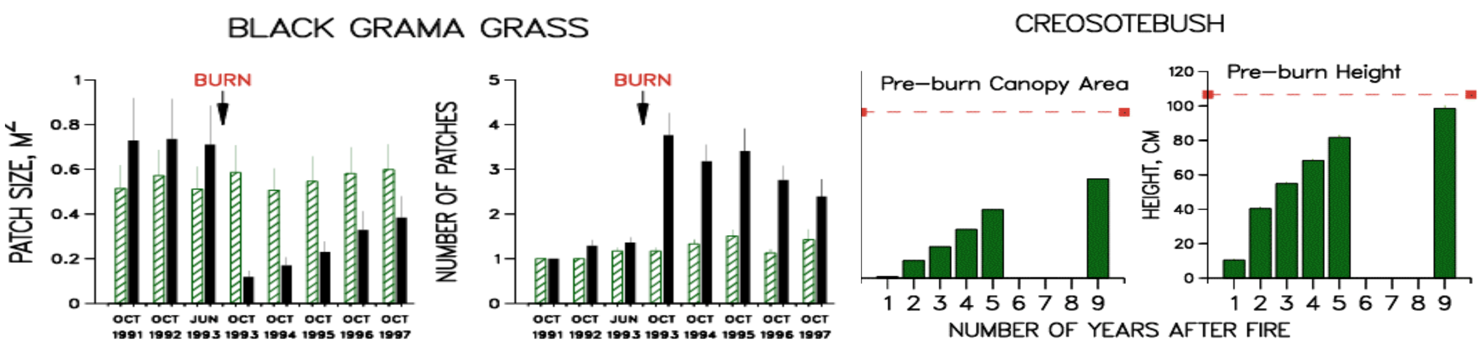
Possible examples of biotic control are illustrated in the two figures below.

Figure 2. Creosote decomposed more rapidly than the other species at all sites. Average initial C:N of creosote litter was 21, while initial C:N of juniper, ricegrass, blue grama and black grama ranged from 65-75.

BIOTIC RESPONSES: PRODUCERS AND CONSUMERS

One of the key questions in arid systems is whether or not black grama (*Bouteloua eriopoda*) can recover from summer fire. Long-term vegetation studies following a wildfire in 1995 suggest that it does recover but more slowly than its main competitive, blue grama (*B. gracilis*). Follow-up studies are now underway following the 2003 management burn where we established monitoring plots prior to the burn (Figure X).

Figure X. Response of black and blue grama and creosotebush to a summer fire.



OTHER ACCOMPLISHMENTS AND FUTURE GOALS

One of the challenges for any LTER site is to seek a balance between understanding the details of a particular research site and addressing a suite of broadly based questions derived from ecological theory. We believe that research at the Sevilleta LTER site has led to a number of significant accomplishments of broad scientific significance and of relevance for the growth and maturation of the SEV LTER Program. Here we highlight several of those accomplishments and then describe our objectives for the next phase of research and development of the program..

Long-term research at the Sevilleta has documented the considerable resilience of these nutrient-poor, aridland ecosystems to disturbances, such as fire and grazing (e.g., Gosz and Gosz 1996, Ryerson and Parmenter 2001, Peters 2002a,b). The region has a long history of grazing, and in some cases, this has led to significant ecosystem degradation. In addition, the site has experienced several lightening-caused fires over the past 10 years. In both cases, there is clear evidence that species composition, soil resources, and standing crop biomass have returned to predisturbance conditions relatively rapidly (Munson et al., in prep). This resilience is somewhat surprising given the extreme environmental constraints that govern biotic processes in this region.

When the Sevilleta began, many thought that biotic transitions in the Southwest would be strongly driven by interannual variation in climate, particularly in response to ENSO events. However, long-term research at the Sevilleta demonstrates that this original ENSO hypothesis is not correct. Not only are these ecosystems resilient over time, but they also appear to be relatively stable across large spatial scales. There is little evidence of large-scale biotic transition being driven by ENSO events (Li 2000, 2002).

Detailed mechanistic studies coupled with long-term data led us to conceptualize a broadly applicable general model of biotic transitions that links patch and edge dynamics (Peters et al., submitted). Traditionally, patch dynamics and boundary dynamics have been treated as somewhat independent phenomena. But, in many cases, the dynamics of a patch are explicitly a function of the dynamics of the patch boundary. As landscapes worldwide continue to be modified by human activities, boundaries will be an increasingly important feature of landscapes. Our patch dynamics-boundary dynamics model can provide a framework for understanding the causes and consequences of landscape change in other ecosystems.

Through a suite of observational and manipulative experiments, we have gained knowledge that is specific to the Sevilleta study area concerning end-member interactions and dynamics in each of our study systems (e.g., Gosz and Gosz 1996, Peters 2002, Bhark and Small 2003). By end-member interactions we mean detailed understanding of pattern and process in core areas dominated by blue grama, black grama, creosote bush, riparian forests, and piñon-juniper woodland. Through this knowledge, we will now begin to expand our efforts into more complex mixtures of species to more fully understand the dynamics of biotic transitions in space and time.

One of the advantages of LTER is the opportunity to establish long-term experimental manipulations that provide the foundation for integrated studies of ecological systems. To that end, we have garnered external funding to initiate a long-term, integrated rainfall manipulation experiment. Rainfall manipulation shelters are being used to modify ambient climatic variables to allow us to more fully understand the role of water inputs and fluxes in these arid land ecosystems, as well as how well these ecosystems recover from extended drought.

LTER programs generate a considerable amount of complex data, and information management is one of the key goals of the LTER Network as a whole. The Sevilleta LTER has implemented an information management system fully in compliance with LTER Network goals and objectives. The information manager interacts with researchers from project inception to conclusion to ensure that well-documented, high quality data are archived and made publicly accessible within two years after the project ends. Research at the Sevilleta is supported by a UNIX server offering file, web, and email services as well as software including SAS, ArcInfo and ERDAS Imagine. Synthethic research and educational activities by the broader community of ecological scientists is fostered by Sevilleta contributions to network-level databases such as ClimDB, translation of Sevilleta metadata into EML (the LTER network metadata standard), and participation in research projects such as SEEK, the Scientific Environment for Ecological Knowledge.

Finally, the Sevilleta LTER is proud of its educationally ambitious and scientifically rigorous Schoolyard LTER Program. This program, the Bosque Ecosystem Monitoring Program (BEMP), meets national and state educational standards for science education, involves over hundreds of school kids each year, connects K-12 students and teachers with UNM undergraduate interns and faculty, provides a source of curriculum activities for school teachers, and produces scientifically rigorous long-term data on the riparian ecosystems of the middle Rio Grande Basin. Currently, BEMP includes 14 school systems throughout the Middle Rio Grande Basin, including two Indian Pueblo schools, a variety of schools in the City of Albuquerque, plus rural school systems as far south as the Sevilleta.

Over the past year, the Sevilleta LTER Program has changed dramatically in response to unfavorable proposal reviews and the last site visit. In direct response to these criticisms, the program has (1) acquired new leadership, (2) broadened the overarching conceptual framework, (3) recruited new investigators especially from within UNM, (4) regionalized the research program, and (5) created new opportunities to enhance graduate and undergraduate participation. With these changes, we feel confident that the SEV LTER can and will remain a strong and viable member of the LTER Network well into the future.

INTRODUCTION

The Sevilleta LTER Program joined the LTER Network in 1988. Formerly, the overarching goal of the Sevilleta LTER was to understand the causes of biotic transitions at multiple spatial and temporal scales, and the consequences of those transitions for ecosystem structure and function. Although this was a broader framework than that used to organize the original Sevilleta research program, the focus on biotic transition zones did not fully incorporate the breadth of research activities now being conducted by the Sevilleta LTER, not did it accommodate needed changes in research foci of general relevance to aridland ecosystems and ecological theory. Based on the recommendations of the 2003 site visit team, we have continued to modify our overarching conceptual framework and our LTER research organization so that we can more fully integrate the components of our research program as well as test important hypotheses of general ecological interest. Therefore, our current overarching framework is now: **Abiotic pulses and constraints: effects on dynamics and stability in aridland ecosystems.** Although it has long been recognized that aridland ecosystems are subjected to the vagaries of precipitation events (Noy-Meir 1973), the role of pulse events in arid environments is now receiving considerable research attention (Huxman et al. 2004). Our new framework will allow us to better integrate our activities within three distinct ecosystems (piÒon-juniper woodlands, desert grassland to shrubland transition, and the Rio Grande riparian zone) at the Sevilleta where several key abiotic drivers (drought, fire, flooding) affect ecosystem dynamics at multiple spatial and temporal scales. Our earlier conceptual approaches (e.g., patch dynamics) have not been abandoned; rather they are now embedded within our newer, more inclusive framework. Indeed, our plant community research is still strongly tied to the theme of patch dynamics (e.g., Peters et al. submitted). Thus, our new framework allows us to continue well-established long-term experiments and measurements as well as add new manipulative experiments and long-term measurements to address additional questions of general ecological interest. New research will be centered on, for example, understanding how the size and frequency of precipitation events drive ecosystem dynamics and how predicted changes in climate variability will affect the future of aridland ecosystems.

To facilitate implementation of this framework, we have organized our research activities into five inter-related research working groups (group leaders in parenthesis): (1) climate variability (Cliff Dahm), (2) water in the environment (Will Pockman), (3) biogeochemistry (Bob Sinsabaugh), (4) producers (Esteban Muldavin and Deb Peters), and (5) consumers (Blair Wolf). These group leaders plus IM Kristin Vanderbilt, Field Crew Leader Karen Wetherill and PI Collins make up the Sevilleta LTER Executive Committee. In addition, May 2004 we hired Mike Friggens to replace Bob Parmenter as SEV LTER Project Manager who resigned in May 2003 to take a job as Director of Science at the Valles Caldera National Preserve. Mike has greatly improved our project organization and our communication with staff at the Sevilleta National Wildlife Refuge.

In this report, we will focus on a subset of our activities and findings in 2004. Many of these studies are on-going because our field season does not end until well after our annual report is due.

ACTIVITIES

Continued activities: In 2004 we continued our long-term data collection activities at our main upland and riparian sites on and around the Sevilleta. These activities include comprehensive meteorological measurements at seven locations, as well as sampling of small mammal populations, ground-dwelling arthropods, grasshoppers, bees, net primary production and plant phenology at three core sites on the Sevilleta. In addition, we continue to maintain CO_2 and ET flux towers as follows: two CO_2 towers in grassland, one in creosote shrubland and one in a Russian olive stand in the Rio Grande bosque. Three of these towers (shrubland, bosque and one grassland tower) also include Bowen ratio measurements of ET. 2004 will be the tenth year of data collection on our long-term small mammal exclosure experiment established through an LTER cross-site award to Dave Lightfoot in 1995 with data collection and management provided continuously since 1995 by the Sevilleta LTER. In addition, we continued to collect data from two sets of long-term permanently located grassland vegetation transects. These sets include two 400-m line-intercept transects in unburned grassland and four 100-m transects across a boundary between twice burned (1995, 2003) and once-burned (2001) areas.

In addition to these long-term studies, we are now into the fourth year of our long-term rainfall manipulation experiment in grassland, grass-shrub transition and shrubland areas at the Sevilleta. In these experiments, we are using water addition plots, rainout shelters and untreated control plots to determine the

effects of extended drought and extended mesic periods on grass and shrub productivity and species interactions. After imposing rainfall manipulation treatments, we measure seasonal growth and physiological responses of grasses and shrubs in drought and water-addition plots relative to untreated controls to assess the effect of extended climate extremes on ecosystem productivity and encroachment of woody shrubs into semiarid grassland. These experiments are also designed to determine whether ecosystem response is determined by immediate differences in grass and shrub structural and functional characteristics or whether the response develops over time as ecosystem modifications accumulate.

In 2003-2004, we focused on completing the sampling of the vegetation patterns at the SEV. We stratified our sampling by boundaries or ecotones between two major grass species, blue grama and black grama. We selected five ecotones between blue grama and black grama dominated communities for intensive study. Four 150 m long transects were located that traversed each ecotone. The following data were collected every 5 m along each transect (n=1440/data type): elevation (mm) using a Total Position Station, vegetation cover by species in 0.5 m^2 quadrats, and the spatial coordinates using a Geo Positioning System (GPS). For two transects, we collected soil samples every 5-10 m from three depths (0-1, 1-5, 5-20cm). We also geo-referenced the location of each ecotone and surrounding community. We are continuing to conduct particle size distribution analysis on the soil samples, and are working with a GIS technician to overlay our data layers with existing GIS layers from the Sevilleta LTER.

New research activities: This year, we began a set of intensive measurements of species composition, microbial diversity and dynamics, N_2O flux, and NPP on a set of long-term fertilizer addition plots in desert grassland. Like the small mammal exclosure study, these plots were established in 1995 through an LTER cross-site grant to Edie and Mike Allen (UCR) and Nancy Johnson (NAU) study the effects of N dynamics and climate variability on mycorrhizal colonization, composition and dynamics (see Johnson et al. 2003). Twelve of the 20 plots also have minirhizotrons that have been read three times each year since 1995. The additional measurements we are gathering starting in 2004 will help us better understand biogeochemical processes and nutrient limitation in these grasslands, and how these processes affect NPP and plant community composition and dynamics. These data will then be added to a large on-going cross-site research activity on productivity-diversity-plant traits which, thus far, is using data from fertilization experiments at 9 LTER sites and one non-LTER site.

This year, the Sevilleta LTER program established seven new sites for annual measurement of net primary production bringing the total number of upland ANPP sites to 10. Two of these sites are located in burned and unburned grassland, two (burned, unburned) in the grass-shrub transition zone, one new site in burned creosote shrubland to compliment measurements at our existing core shrub site, one site in the piÒon-juniper woodlands, and one in the long-term N fertilization experiment in grassland. NPP is measured using the non-destructive allometric approach developed at the Jornada LTER (Huenneke, et al. 2001). This method allows us to make non-destructive, long-term NPP measurements within our manipulative experiments as well as at our core sampling sites.

In addition to our new efforts at the N-fertilization site, we have established new long-term measurements of plant species composition and soil N dynamics in two large mammal grazing exclosure experiments. The first experiment includes three 300x300 m^2 replicates of the following treatments: (1) grazed by cattle, (2) recently ungrazed (fenced in 1993) and (3) long-term ungrazed (fenced in 1973). The purpose of this experiment is to estimate rate of ecosystem recovery following removal of cattle in desert grassland. The second grazing experiment includes four 300x300 m^2 replicates of the following treatments: (1) unburned, ungrazed, (2) unburned, grazed by native ungulates (antelope), (3) burned, ungrazed, and (4) burned and grazed. Measurements in each replicate include plant species composition, soil nitrogen (resin bags, lab incubations) and peak standing crop biomass.

Information Management: The Sevilleta unveiled a new website in January 2004 (http://sev.lternet.edu). Sevilleta IM personnel Kristin Vanderbilt (Information Manager), Mike Friggens (Program Manager), and Harsha Belludi (student programmer) collaborated with Marshall White from LNO to design and implement this new site in the PostNuke content management system. In addition to a fresh look and feel, the new web site is more intuitive to use and has much more dynamically generated content. Several of Sevilletaís new datasets are now being managed in MySQL and are queryable from the new website. Renee Brown, Sevilleta system administrator, has also established an intranet, which is a new feature of the Sevilleta website. Web-based data entry programs being developed by Harsha will be accessible from the intranet, as will WebMail, a new email client made available to Sevilleta associates in July 2004.

EML implementation at the Sevilleta has been a struggle. LNO personnel determined in late 2003 that extant Sevilleta metadata are unstructured enough so as to be impossible to parse into EML. Janine McGann of LNO therefore cut and pasted metadata from a few Sevilleta datasets into EML to serve as examples for converting the rest of the legacy metadata. A few legacy datasets at the Sevilleta have since been agonizingly converted into attribute-level EML using Morpho. The rest of the legacy data will be converted into discovery-level EML during the next year as time permits.

To capture new metadata as EML, Kristin Vanderbilt cooperated with Linda Powell at FCE and programmer Gaurav Gupta at LNO to devise an Excel template for metadata input and a Java application that would translate it into EML. This project was abandoned by LNO after months of work following the departure of Gaurav Gupta in favor of creating a new, web-based data entry application. The capabilities needed from this tool were discussed by James Brunt, Mark Servilla, Linda Powell and Kristin Vanderbilt in early June 2004. Development of this application was placed fourth on the list of priorities for the NIS development team by NISAC. Sevilleta therefore expects to await the completion of the Excel to EML tool that is now being developed by FCE personnel. The tool was demonstrated by Linda Powell at the 2004 LTER Information Managersí meeting in Portland, OR. It will not be completed until the EML Best Practices Committee releases its report.

Information gathering: With funding from a Biological Field Stations and Marine Lab award and UNM cost-share, the Sevilleta LTER has installed Phase I of a wireless backbone that will cover the east side of the Sevilleta National Wildlife Refuge. The purpose of this backbone is to allow us to collect, transmit and store data from research projects in real time via wireless technology. The system we constructed begins with a wireless backbone obtained with paired Trangolink10 master and remote units operating at 5.8 ghz. The master unit is on the roof of our main Field Station building. The remote unit is on top of a peak in the Los Pinos. The remote Trango unit in the Los Pinos connects to a D-Link hub. From that hub the system becomes a standard 2.4 ghz 802.11b network. This network includes two access point radios (Smartbridge Airpoint Prototals) that connect to the same D-Link hub. One of these is set on channel 1 and is pointed at the middle to northern portion of Mckenzie flats. The other is set to channel 11 and is pointed to the southern part of Mckenzie flats including Palo Duro canyon.

The Annual Sevilleta Research Symposium and Workshop: The Annual Sevilleta Research Symposium was held on the UNM campus in January 2004 followed by a poster session and all day workshop at the Sevilleta Field Station. The meeting was attended by approximately 60 LTER researchers (senior personnel, UNM faculty, FWS staff, students, research staff), and included both oral presentations and posters. The workshop is used to determine the schedule of our upcoming research activities and to discuss new research projects.

Educational Activities. We have greatly increased our graduate student training activities over the past two years. During 2004, we provided summer stipends and/or other support (computer, laboratory, field vehicles, etc.) for >12 graduate students and one postdoc from UNM, University of Colorado, UC Riverside and the University of Nebraska. The Sevilleta LTER program also offers research experiences for several undergraduate students. In 2004, we supported two REU students with an LTER REU supplement. One student, Casey Gilman, a UNM undergraduate, worked with PIs Blair Wolf and Eric Toolson on ecophysiology, fecundity, and population dynamics of collard lizards in and around the Sevilleta. A second student, Renee Ziemann from Seattle Pacific University, worked with PI Collins and SEV staffer Jennifer Johnson to assess the ability of roads and property boundaries to serve as conduits for invasive species into the Sevilleta National Wildlife Refuge. The Sevilleta Schoolyard LTER program continues its active research and education program both in the classroom and at a variety of field sites along the Middle Rio Grande Valley in collaboration with 16 school systems in New Mexico including the Albuquerque Public Schools, private schools, a home school, rural schools and two Pueblo schools north of Albuquerque. In 2004, the Sevilleta LTER received an additional education supplement to host a SEEDS workshop at the Sevilleta Field Station in partnership with ESA. Because of scheduling conflicts, this workshop must be postponed until November 2005, but we have already begun planning for this workshop as well as creating a plan to convene SEEDS workshops at other LTER sites. Finally, Sevilleta scientists continue to participate in a variety of formal and informal public outreach activities, including research tours, classroom visits, working with High School sciences classes at the Sevilleta and organizing information booths at public events (e.g., the New Mexico State Fair).

Cross-Site and LTER Network-Level Activities. Sevilleta LTER scientists continue to participate in numerous cross-site research projects (with both LTER and non-LTER sites) and LTER Network-level activities. For example, Sevilleta LTER scientists Collins and Peters participated in a recent cross-site synthesis on climate change and disturbance held in June 2004 at the University of Wisconsin (NTL) and at the 2004 CC meeting hosted by the Bonanza Creek LTER. PI Collins is a participant in an intersite initiative to use common stream invertebrate datasets to assess core-satellite species distribution and meta-community structure in space and time. The core-satellite and metacommunity working group presented papers at the 2004 NABS and ESA annual meetings, including an undergraduate as the lead author on the ESA presentation. SEV PI Collins is the lead PI, along with Katie Suding (NWT) on an RCN proposal to support further synthesis by the productivity-diversity-plant traits network group which was established through LTER Network Office support. This collaboration has already generated two recently submitted manuscripts.

The Sevilleta continues to serve as a desirable site for externally funded ecological research. For example, David Hartnett at Kansas State University and his students are using the Sevilleta in their new cross-site study of belowground plant meristematic bud banks. Nathanial and Peggy Ostrom, Michigan State University, are using the N addition plots at the Sevilleta in their cross-site research on isotopomers and N_2O flux, bacterial composition and denitrification from terrestrial soils. Bruce Hayden and Jose Fuentes from the University of Virginia recently installed towers and monitoring equipment at the Sevilleta to determine the kinds of volatile compounds being emitted from creosote and weather or not these compounds can modulate winter low temperatures above creosote bush stands. Chris Duffy from Penn State University is working with PI Dahm at a site in the Rio Salado on the Sevilleta to assess the relative roles of

evaporation and transpiration in riparian zones. Several streams within central New Mexico, including streams on the Sevilleta, are part of a multisite NSF-funded project on nitrate uptake and retention in streams. Participants include UNM PI Dahm and LTER Graduate students Chelsea Crenshaw and Lydia Zeglin. The NM portion of this project is part of a regional collaboration between SEV and CAP LTER scientists.

Sevilleta scientists continue to make significant contributions to LTER Network-level activities. Sevilleta PIís Gosz and Collins are the lead PIís on the recently funded LTER Planning grant whose goal is to take LTER science to a new level of regional science, collaboration and synthesis, one that fully integrates research and education. Jim Gosz was recently re-elected as Chair of the LTER Coordinating Committee and Collins was elected to serve on the LTER Executive Committee. IM Kristin Vanderbilt continues to serve on the US ILTER committee and on the IM Exec Committee. She also collaborated with Longjiang Ding and Peter Arzberger at the San Diego Supercomputer Center to organize the January 2004 web services training workshop for LTER information managers and international IT personnel. She contributes to the NSF ITR SEEK (Science Environment for Ecological Knowledge) project by co-teaching workshops for post-docs in ecology, and also co-teaches information management workshops for personnel from the Organization of Biological Field Stations (OBFS) in support of an RCN proposal with LNO. Project Manager Friggens also leads GPS training activities organized by SEEK.

International Activities. International activities by Sevilleta LTER scientists include participation by Information Manager Kristin Vanderbilt in an ILTER-sponsored meeting of the Environmental Long-Term Observatories Network of Southern Africa (ELTOSA) in Botswana (October 2003). In May 2003 and again in June 2004, PI Collins participated in an NCEAS-sponsored Knowledge Network for Biocomplexity workshop that focused on ecological comparisons of North American and South African grasslands (Knapp et al. 2004). In 2004, in collaboration with KNZ (Blair) and SGS (Knapp), the Sevilleta LTER received an ILTER supplement to establish additional collaborative research with colleagues in South Africa. Using start-up funds, Collins will be going to Kruger National Park in October 2004 for a preliminary visit and plans are developing for the three site collaborators (Blair, Collins, Knapp) along with a graduate student from each site to begin data collection in collaboration with South African scientists using the ILTER supplement funding.

SEVILLETA RELATED ACTIVE EXTRAMURAL GRANTS - 2003-2004.

The Sevilleta LTER program continues to work hard to leverage our LTER core funding. Below we list non-LTER grants that were active during the 2003-2004 reporting period. These grants include funding for Sevilleta research activities, graduate training, research infrastructure and network-level collaborations.

Pockman, W.T. and E.E. Small. Impact of climate variability and woody encroachment on productivity in a semiarid grassland in New Mexico. DOE National Institute for Global Environmental Change, 9/1/03 ñ 8/31/06, $287,880.

Yates, T. and R.R. Parmenter. EID: Ecological Drivers of Rodent-borne Disease Outbreaks: Trophic Cascades and Dispersal Waves. NSF-NIH Special Competition: Ecology of Infectious Disease Program, 9/1/03 ñ 8/31/07, $1,700,000.

Wolf, B. SGER: Using Portable Ultrasonography to Quantify Life History Traits and Energetic Status of Small Animals in the Field. NSF Ecological and Evolutionary Physiology Program, 06/01/04 ñ 11/01/05, $50,492.

Milne, B.T., D. Bader, W.T. Pockman and C. Restrepo. Self-organization of semi-arid landscapes: Tests of optimality principles NSF Ecosystem Studies Program, 1/1/00 ñ 2/28/04, $674,911.

Dahm, C.D. Nitrate uptake and retention in streams: mechanisms and effects of human disturbances from stream reaches to landscapes. NSF IRCEB Program, 8/1/01 - 7/31/06, $$ (UNM subcontract on award to ORNL).

Ward, A.K., A.C. Benke, C.N. Dahm, W.B. Lyons, and R.G. Wetzel. IGERT: Freshwater graduate studies link fundamental science with applications through integration of ecology, hydrology, and geochemistry in regions with contrasting climates. NSF-IGERT Program. 1/1/99 ñ 12/31/05, $2,699,289.

Pockman, WT, D.O. Natvig, S.L. Collins, C.D. Dahm, R.R. Parmenter. The Sevilleta Research Field Station: infrastructure enhancements for high-quality water resources and wireless data transmission. NSF Biological Field Stations and Marine Labs, 12/1/03 ñ 11/30/06, $76,270.

Gosz, J.R., S.L. Collins, B. Benson, D.L. Childers, A.C. Whitmer ñ Preparing the LTER Network for collaborative science, education and synthesis: a planning grant. $985,462, 9/1/04 ñ 8/31/06.

FINDINGS

Here we present a subset of results from Sevilleta research in 2004.

Climate change and climate variability at the Sevilleta (PIís Cliff Dahm, Will Pockman, Scott Collins, LTER Staff Doug Moore, PostDoc Joe Fargione): In preparation for establishing new climate manipulation experiments including infrastructure that will allow us to (1) control the size and frequency of rainfall events as well as event size, and (2) create warmer winter days and nights, we analyzed climate variability from the main meteorological station on the Sevilleta at Deep Well. Results show that daily highs during January, the coldest month have increased nearly 2oC from 1989 to the present, whereas nighttime lows have only increased marginally if at all. Summer high temperatures during the warmest months are also increasing, and the seasonal variation in the size of rainfall events at the Sevilleta is increasing (Fig. 1). These results are in keeping with global change models that predict warmer temperatures and more variable precipitation events in the future. We are using this information to help us design experiments that will use a new irrigation system, located in conjunction with the rainfall manipulation plots to test hypotheses concerning how the size and frequency of rainfall events affects soil nutrient availability, ANPP, decomposition, and population and community dynamics. In addition, this winter we will be prototyping open-topped chambers to allow us to passively warm small experimental plots either in winter daytimes, nighttimes or both.

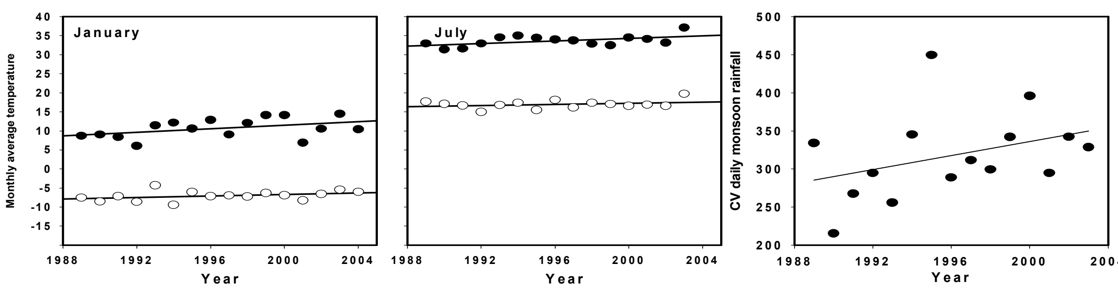


Figure 1. Change in average monthly high and low temperatures in January and July at the Deep Well site. In both months, the average high temperate has increased nearly 2oC over the past 15 years. In addition, the coefficient of variation of the size of daily monsoon rainfall events has increased. Thus, the climate is getting warmer and precipitatin is becoming more variable over time.

Sevilleta Groundwater and ET in the riparian zone (PI Cliff Dahm, Research Scientists James Cleverly and Jim Thibault): Groundwater elevations and rates of evapotranspiration (ET) have been measured in the riparian zone along the Rio Grande at the Sevilleta LTER since 1999. The site is an area dominated by the non-native salt cedar (*Tamarix chinensis*) and native salt grasses. The area rarely sees flooding and stand density is at the lower end of riparian habitats along the Rio Grande in central New Mexico. Figure 2 shows ET for the growing season of 2003. Background ET rates of generally less that 1 mm/day occur until leaf out in late April to early May. ET rates increase rapidly to maximum values above 6 mm/day in late June and July with decreased rates in August and September. Senescence in October is followed by a return to baseline ET rates after the first hard freeze in early November. The average annual growing season ET for the site in 2003 is estimated at 68 cm. Interactions between ET and ground water elevation are apparent in Figure 2. Water tables are highest at the beginning of the growing season and drop progressively throughout the growing season. The downturn in ET late July, August, and September correlates well with the greatest depth to ground water at three wells within the Sevilleta study site. Groundwater elevations rebound at the end of the growing season and after the first strong freeze of early November. These data were recorded during the fourth year of a long-term and strong hydrological drought in the region. The response of native and non-native

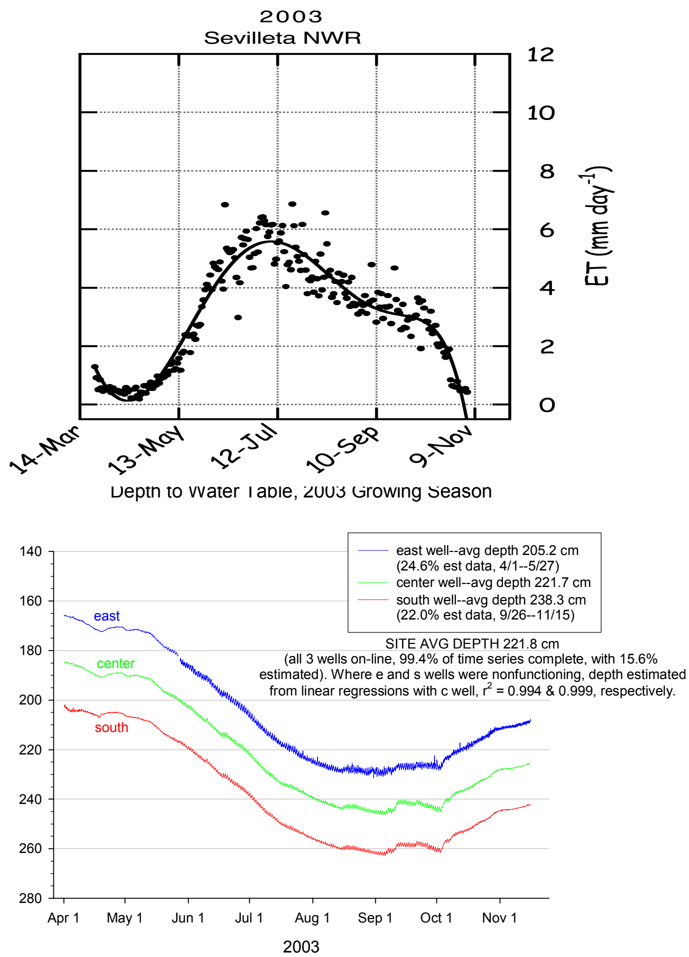


Figure 2. Top panel: annual track of evapotranspiration at the La Hoya site on the Sevilleta. Bottom panel: ground water levels in the riparian zone at La Hoya, NM.

vegetation of riparian zone plant communities along the Rio Grande to this intense drought is an ongoing long-term research interest of the Sevilleta LTER. In addition, understanding the role of riparian vegetation for the regional water budget of the Rio Grande is a focus for this long-term research project.

Effects of wildfire on plant and soil chemistry in a Rio Grande riparian forest (Graduate students: Mary Harner, Jennifer Follstad Shah, Teresa Tibbets, Chelsea Crenshaw, and Jennifer Schuetz): Riparian forests of the southwestern

United States have evolved under the influence of flooding disturbances. Increasingly, these forests are experiencing more disturbances by fire than by floods. A fire in April 2003 burned a long-term research site along the Rio Grande, New Mexico, which provided an opportunity to study the influence of fire on this ecosystem. Soil inorganic N; leaf chemistry of cottonwood, salt cedar, and Russian olive plants (mature leaves pre-fire; re-growth post-fire); soil moisture; and soil temperatures were monitored before and after the fire. Mean soil temperature was 5.6 °C higher at the burn site compared to three other unburned riparian sites. Inorganic N in soils was 16.4 mg N/kg dry soil in June 2003 following the fire compared to 4.7 mg N/kg dry soil in June 2002. Soil inorganic N exhibited a strong, positive linear correlation with subsurface soil temperature after the fire. Leaf C:N ratios were low (molar C:N < 20) from all three plant species, and cottonwood leaves sampled post-fire contained more nitrogen than leaves sampled pre-fire (Fig. 3). Fire, in combination with hot, dry conditions, increased the availability of soil inorganic nitrogen, which was reflected in an altered chemistry of plant leaves.

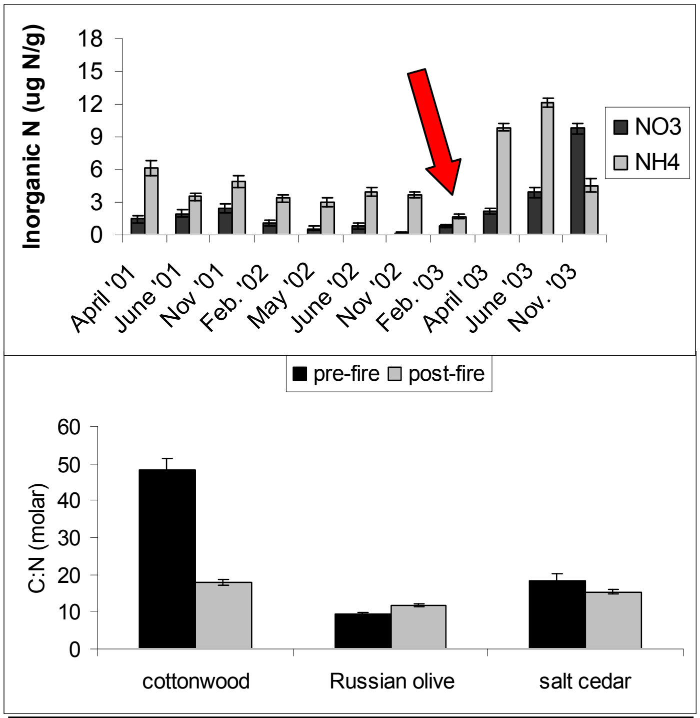


Figure 3. Top panel: Available ammonium and nitrate at 10 cm depth before and after wildfire at Bernardo, NM. Arrow denotes date of wildfire in early April 2003. Bottom panel: Comparison of leaf chemistry (ratio of molar carbon to nitrogen) of leaves from cottonwood, Russian olive, and salt cedar before and after Bernardo wildfire. Leaves were sampled in August or October.

Productivity and species composition in the rainfall manipulation plots (PIís Will Pockman, Eric Small; Grad student Shirley Kurc; Sev LTER staff Jennifer Johnson, Jim Elliott): Aboveground net primary productivity (ANPP) is measured annually for grasses and 3 ñ 5 times per year for shrubs (March, late June, and October). Shrub ANPP is measured using allometric methods based on the change in size of first order twigs. Grass ANPP is measured with destructive sub-sampling of 5, 10 x 10 cm areas per plot. Samples are sorted to separate green biomass before drying and weighing. These samples also allow calculation of LAI for grasses by separating leaf tissue and using a regression between leaf area and mass.

Over the first two years of treatment, shrubs have not exhibited significant differences in twig growth between control and rainout plots (Fig. 4). In contrast, we have observed a significant decrease in ANPP between control and rainout plots at the grassland site. This trend has also been observed at the ecotone plots (data not shown) but has not been significant.

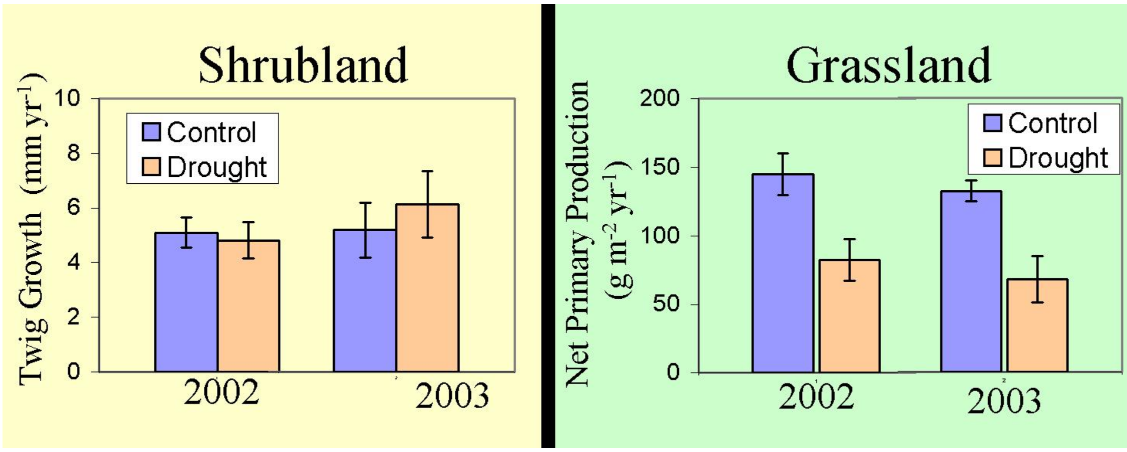


Figure 4. Effect of experimental drought on creosote bush twig growth at the shrub-dominated site and ANPP at the grassland site in 2002 and 2003, a year of low exceptionally low summer rainfall.

For comparison with species productivity data, plot scale plant cover and bare soil are assessed with overhead photos collected using a digital camera and analyzed using ArcGIS software. Three cover types have been identified: (1) shrub canopy; (2) grass canopy and surrounding litter; and (3) interspace. The amount and spatial distribution of different cover types are measured using digital photos (3.34 megapixel) of each plot, collected at peak biomass to capture species dynamics and changes in the drainage network. A Nikon CoolPix 990 camera mounted on a specially designed boom achieves sufficient elevation (7 m) to cover an entire plot with a set of 6 photos. After rectification and assembly, ArcGIS software is used to measure total grass and shrub cover. These mosaics allow detailed, field checked, measurements of changes in grass and shrub size, stone cover, and interspace connectivity. Mosaics are being assembled for each plot on a yearly basis.

Comparisons of overhead photos from Fall of 2002 and 2003 in the control and drought plots indicates that one year of drought treatment has led to a significant decrease in grass cover in the drought treatment of grassland plots (Fig. 5). These cover changes are consistent with the decreased productivity observed in the grass drought plots in both 2002 and 2003 (Fig. 4). Although the decrease in cover may have been exacerbated by low precipitation and late and below-average summer monsoon, no such differences were detected in the control plots over the same period. Overhead photos and productivity measurements from 2004, with a strong ongoing summer monsoon, will help reveal whether this result is indicative of a long-term trend in the drought treatment. If this pattern of decreasing cover continues, we expect to have an opportunity to observe how the drainage network and redistribution of precipitation are affected by long-term drought.

Data from the Sevilleta, including insights from these rainfall manipulation plots, contributed to a cross-site analysis of productivity and ecosystem-scale rain use efficiency published recently in *Nature* (Huxman et al., 2004a).

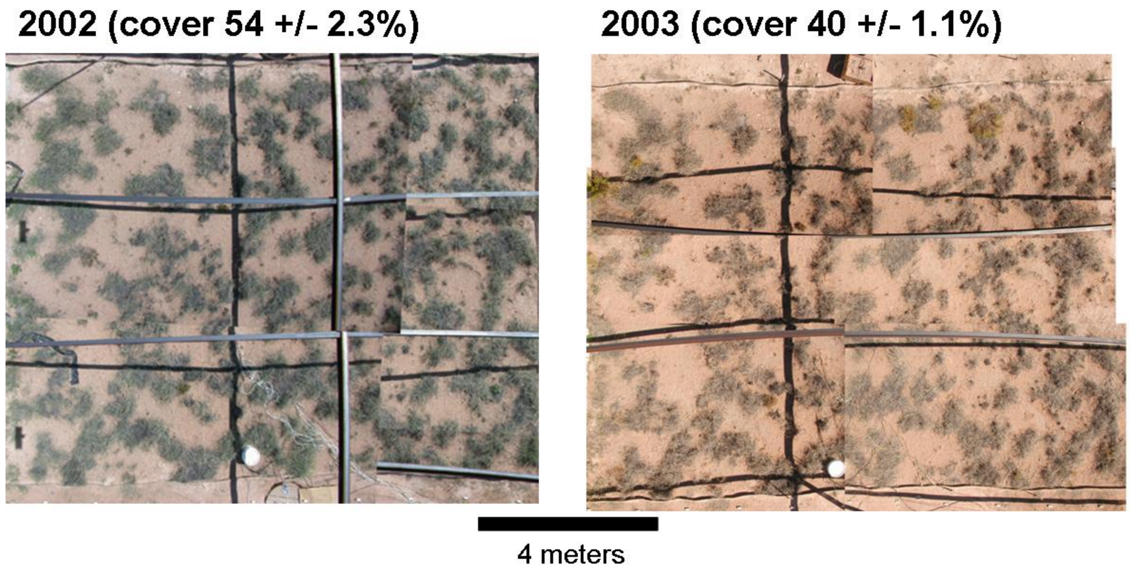


Figure 5. Aerial photo of grassland plots. 2003 was a year of severe drought and the reduction in canopy cover can be easily seen relative to the plots in 2002.

N-fertilization plots (PIís Bob Sinsabaugh, Scott Collins; Grad students Chelsea Crenshaw, Marcy Gallo, Chris Lauber, Lydia Zeglin): Most of what we report here is from a collaboration between graduate students Gallo, Lauber and Zieglin under the guidance of Sinsabaugh and supported by the SEV LTER. In the summer of 2004 soils were collected from beneath the grass canopy and in bare areas within our long-term N fertilized and control plot experiment (N=10). Subsamples of these soils were analyzed as follows. Crenshaw Collins conducted lab incubations of soil samples to determine if carbon and or nitrogen limited denitrification in these soils. Gas samples have been collected and further analysis awaits the arrival of a new ECD for the GC in the LTER analytical lab. This instrument was purchased with a combination of startup, IGERT and LTER funds. Preliminary results from work in Sinsabaughís lab shows that these aridland soils serve as a dramatic contrast to more heavily studied mesic systems. Thus far, we have found that there is a 10X difference between the N addition plots and controls in exchangeable ammonium and and 2-3X difference in exchangeable nitrate (Fig. 6). There is not much difference in SOC with N addition but the C:N ratio in N addition plots is half that of control plots. An extensive survey of soil enzymatic activity is ongoing with plans to assaying 25 enzymes. Results thus far show that glycosidase activities are higher in soil beneath the grass canopy than in the gaps between tussocks (Fig. 7). The addition of N accentuates this pattern; activities increase by 50-100% in canopy

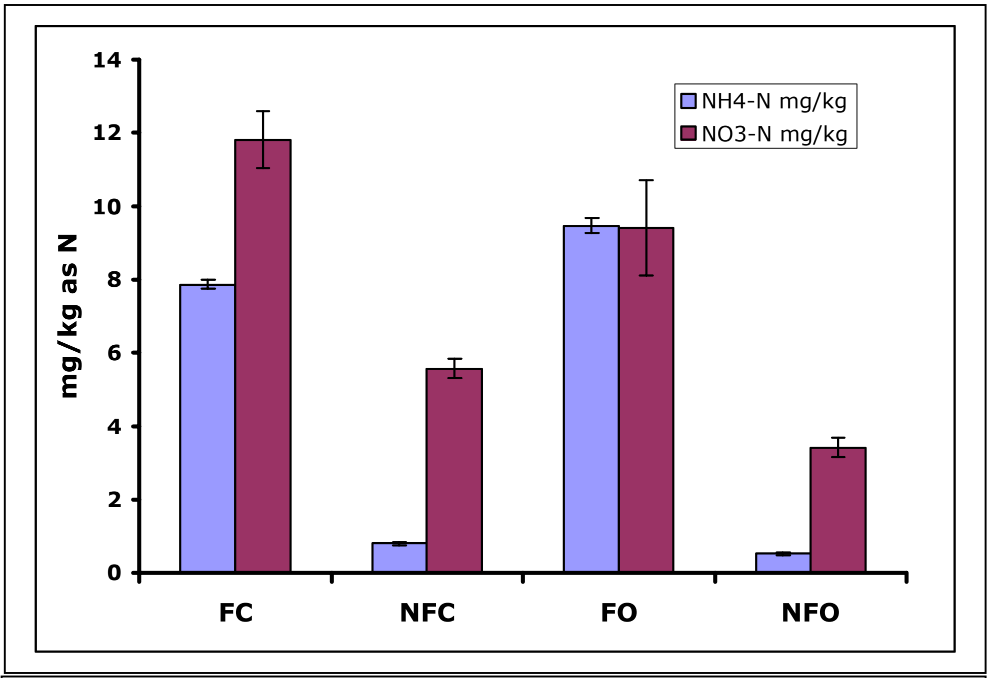


Figure 6. Ammonium and nitrate levels beneath grass canopy (C), and open areas (O) in fertilized (F) and control (NF) plots at the Sevilleta. Results show that NO3-N is generally higher in fertilized plots and under the grass canopy relative to controls.

soils but only ca. 20% in gap soils. Peptidase activities show the opposite pattern, activities are higher in the gaps than under canopy. N addition represses activity by 50% or so with the biggest effect in the gaps. Aminohydrolase activities follow a similar trend. Laccase and peroxidase activities are flat with respect to location and N treatment. The same is true for fatty acid esterase, which can be considered a general measure of microbial activity. It is clear that these arid soils are very responsive to N addition, at least as responsive as temperate forest soils. The "anomaly" is the lack of repression of oxidative activity. Because of soil pH and other conditions, fungi are likely to be nearly absent from the microbial community which may be the reason we do not observe oxidation repression. We are still probing for laccase genes and getting phylotypic data to eventually address this hypothesis.

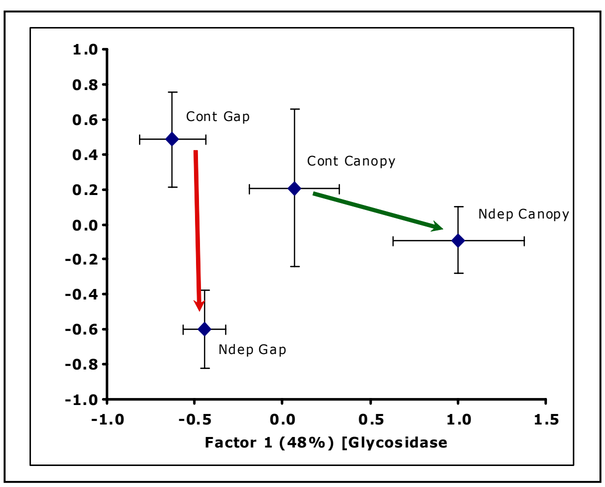


Figure 7. Glycosidase activity beneath grass canopies and open areas in control and fertilized plots (10g-N m^2 yr^2) at the Sevilleta.

Invasibility of the Sevilleta National Wildlife Refuge (PI Scott Collins and REU Renee Ziemann): This summer we tested the hypothesis that a pasture grazed by cattle outside the northern boundary of the Sevilleta could serve as a source area for invasive plant species onto the Refuge. We also tested the hypothesis that roads running from the grazed area onto the Refuge would serve as invasion corridors. To test these hypotheses we established approximately 50 sampling transects perpendicular to the northern boundary and perpendicular to the two main dirt roads entering the Sevilleta from the north. The good news is that there are very few invasive plant species in the grazed area and in the Refuge. Common invasives were Russian thistle and tumbleweed. However, if we consider native weeds (rapidly growing annuals typical of disturbed areas) as surrogates for invasibility, the Refuge is highly prone to invasion. There were few, if any, significant differences in abundance of weedy species in the grazed pasture compared to adjacent grasslands on the Refuge. Also, there were few significant distance effects away from roads or from the fence line. If anything, there is a general increase in weediness away from the roads and fence lines. This results from low plant cover and abundance near roads and a general increase in cover of all species away from roads. Thus, weediness is highly correlated with regional species richness as has been found in many other studies.

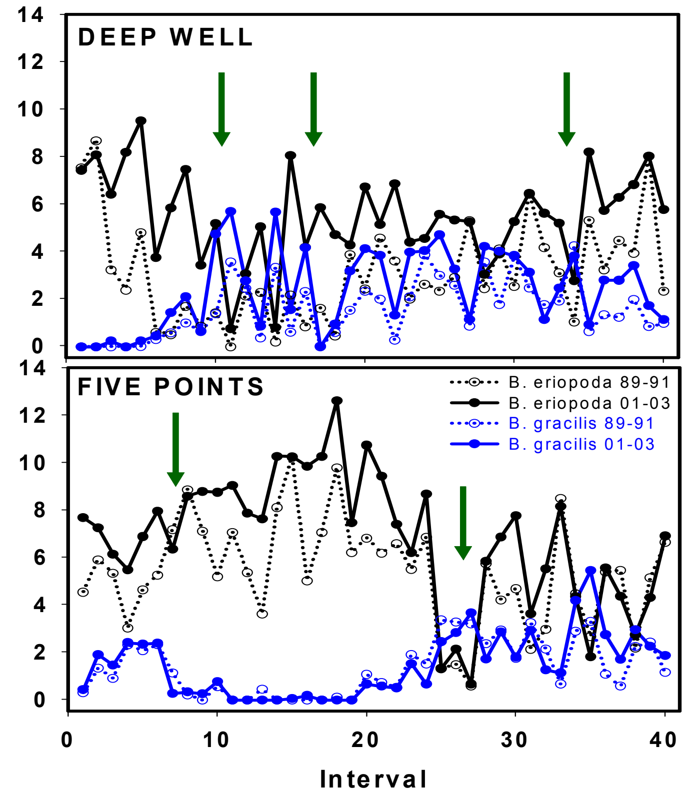
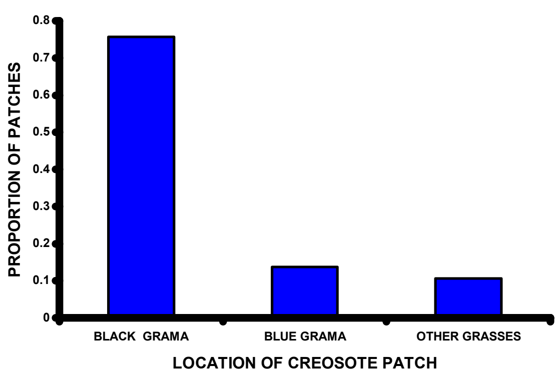


Figure 8. Change in cover of blue and black grama from 1989 through 2003 within 10m intervals along two 400 m line intercept transects (Deep Well and Five Points). Each transect was divided into either three or four larger segments based on compositional variability. Different sections of each transect changed at different rates over the 15 year interval. In some cases the rate of change in one segment was double that of other segments.

Long-term vegetation transects (PIś Scott Collins and Este Muldavin; Sev LTE R Staff Doug Moore and Seth Munson): In 1989, a series of permanently located line intercept transects was established at several locations within the Sevilleta National Wildlife Refuge. Given the significant time commitment needed to sample all transects, only a 400 meter subsection has been sampled annually on two transects since 1989. Along each transect, plant species cover is recorded at 1 cm resolution two times (spring, late summer) each year. This dataset provides a highly detailed documentation of plant species composition and dynamics over the past 15 years. The data have been used for detailed spatial analyses of species distributions and patch structure (Anand and Li 2002, Li et al. 2004). To assess compositional change, transects were divided into 10 m subunits to study the spatial and temporal dynamics of desert grassland at the Sevilleta. Results demonstrate that across the transect as a whole there is a weak positive correlation between summer rainfall and summer forb cover and summer grass species richness. Abundance of the two dominant grasses, blue and black grama, was positively correlated over time. At Deep Well, there is a significant positive correlation between grass and forb cover. The same trend occurred at Five Points, where abundance of black grama is higher, but it was not significant. By aggregating segments based on boundary structure, we found that temporal patch dynamics are occurring at different rates across these grasslands. In some cases one patch type is changing at a rate more than double that of adjacent patches. These different rates occur in response to the interactions among different combinations of dominant species played out across a variable soil texture and nutrient template.

Patch structure and vegetation transitions (Deb Peters): We collected patch size distribution data from the Sevilleta to test hypotheses about ecotone structural and functional properties. Twenty blue grama patches and twenty black grama patches were selected along each transect for a total of 800 blue grama and 400 black grama patches. We also selected all creosote patches (> 300) along 5 50-200m long transects that traversed communities dominated by either blue grama or black grama. Each patch was measured either for two diameters to calculate basal area or for basal area directly. A subset of grass patches was collected for biomass determination. Vegetation cover inside and outside creosote patches was estimated using quadrats. Our results for creosote show that most creosote patches are located within communities dominated by black grama; the few number of creosote patches located within blue grama communities suggests that this grass species is less resistant to invasion by this shrub. We are currently writing a manuscript for publication that describes these results.



Grazing Exclosures (PI Scott Collins, Grad Student Lydia Zeglin, SEV LTER Staff Mike Friggens): In 1993, Three 300x300 m^2 cattle exclosures were established in a grazed pasture on the north border of the Sevilleta National Wildlife Refuge.

Three nearby 300x300 m^2 open control areas and three comparably sized areas were also established in the grazed pasture and on the Sevilleta. The purpose of this experiment was to determine how quickly desert grasslands recovered from moderate grazing. Cattle were removed from the Sevilleta in 1973 when the Refuge was established, thus this experiment has three treatments, currently grazed, recently ungrazed, and long-term ungrazed. A Single small mammal trapping web was located within each exclosure and open area. These webs have 144 sample points marked with rebar located along 12 transects radiating from a central point (Parmenter et al. 2003). In 2004 we selected four trapping points along the outer arm of each web as the location for a single permanent 50x50 cm^2 vegetation quadrat. Therefore, each exclosure and open area now has 48 permanently located vegetation quadrats that will be sampled annually. We sampled vegetation this spring and will complete the fall sampling in September. Other measurements include soil N (N_{min} and resin bags), microbial diversity, and leaf C,N, and P for stoichiometric analyses of the dominant grasses. Results to date indicate that grass C:N is higher in the spring than the fall (plenty of new growth on the grasses in May 2004) due to lower %N and slightly higher %C (%N 1.68 in fall, 1.20 in spring; %C 44.88 in fall, 45.37 in spring). There were no significant differences among grazed areas, exclosures, and plots on the Sevilleta; although the exclosure grass stoichiometry is still

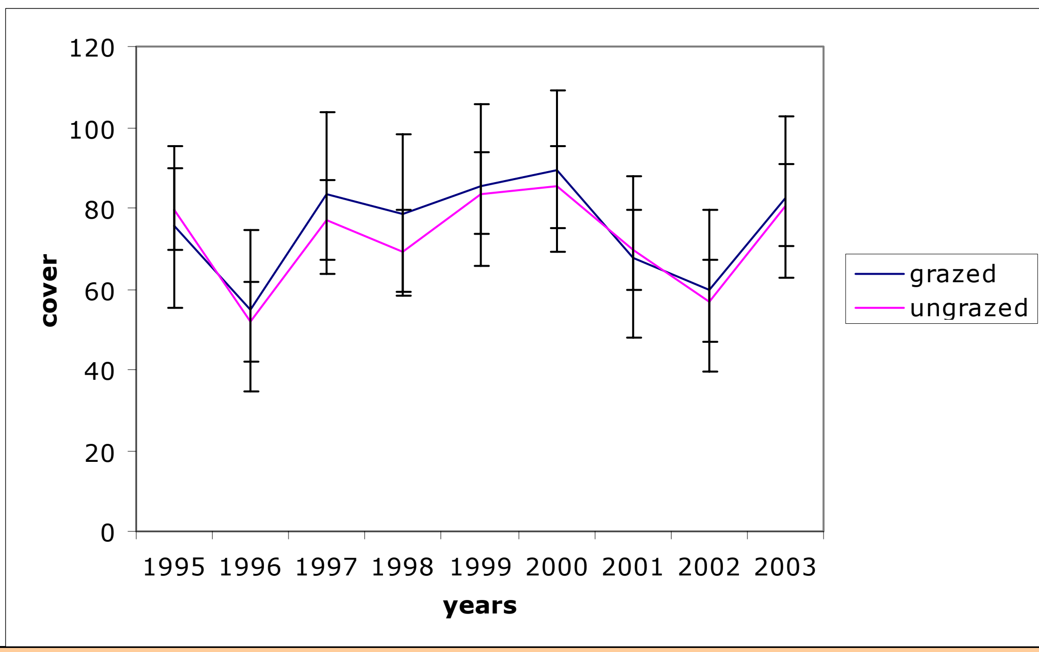


Figure 9. Changes in cover of black grama (*Bouteloua eriopoda*), an abundant C_4 grass in Sevilleta grasslands, from 1995 to 2003 in plots that are open to rodent herbivores (grazed) and plots where rodents have been excluded.

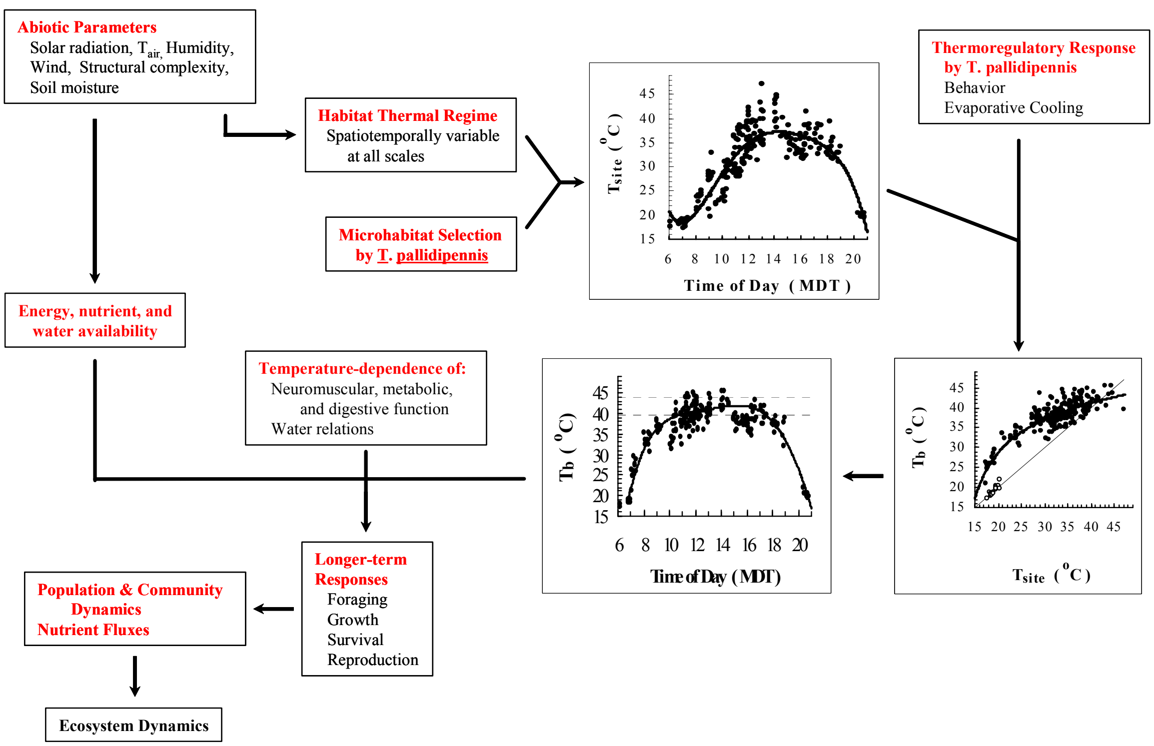
closer to that of the grazed plots than the Sevilleta plots). Grass P data and soil CNP data are still being analyzed.

Small mammal exclosure study (PIís David Lightfoot and Scott Collins, Grad students Selene Baez, Terri Koontz). In the summer of 2004, we began to analyze data from this long-term exclosure experiment. The overarching goal of the small mammal exclosure study (SMES) is to determine the relative impact of small mammals on plant community dynamics in grassland and shrubland vegetation at three study sites: the Sevilleta, the Jornada LTER and Mapimi in northern Mexico. The study is based on the pioneering work of Brown and colleagues (e.g., Brown and Heske 1990) in grasslands at Portal, AZ. Our initial analyses focus on responses in the grass and shrub plots at the Sevilleta. The underlying conceptual framework is based on bottom up controls driven by abiotic factors versus top down controls through herbivory and granivory by small mammals. After nine years of rodent exclosure, there are few overall changes in plant community structure in either the grassland or shrub-dominated areas. In general, total cover, cover of dominant species (Figure 9), and plant species diversity are driven more by year to year fluctuations in climate than they are by the activities of granivores. There is some evidence that community heterogeneity is decreasing in the rodent exclosures. The general lack of response occurs, we suspect, because these systems are dominated by long-lived perennial plants and reproduction by seed is rare. We are still investigating the impacts of granivory on the abundances of annuals and forbs in these plots.

Stoichiometry, energetics and thermal biology of desert herbivores (PIs: Blair Wolf and Eric Toolson, REU Students Casey Gilman, Donna Pham and Josh Nuygen): Grasshoppers are dominant herbivores in desert grasslands yet the role they play in ecosystem structure and function at the Sevilleta is poorly known. In particular, use of resources by grasshoppers is dependant on species abundance, individual species energy requirements and their dependence on element stoichiometry mediated through the plants they eat (Fig. 10). This on-going project takes a mechanistic approach to examining the impact of this key group of herbivores on productivity and nutrient cycling. This is an ongoing project where undergraduate students are developing a data set that will help us better understand the dynamics between consumers and producers in arid environments.

T. pallidipennis Thermal Physiological Ecology

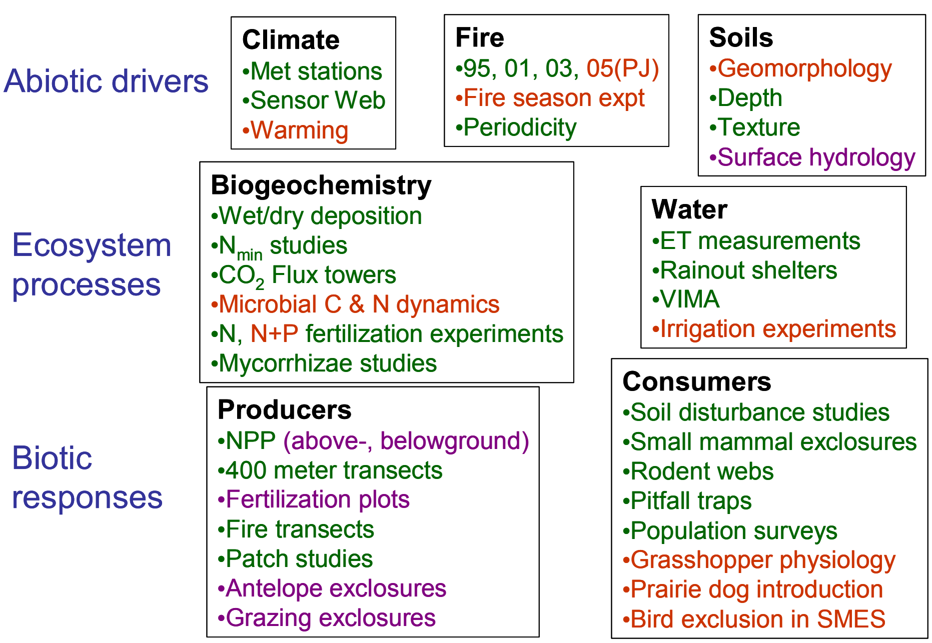
Red font: data required to quantify parameters and/or define mapping functions will be obtained from appropriate lab/field studies currently underway or planned for the near future..



ACTIVITIES

The overarching goal of the Sevilleta LTER Program is *to understand how abiotic pulses and constraints affect species interactions, community structure and ecosystem processes in arid land ecosystems*. The Sevilleta LTER Program is organized around understanding the individual and interactive effects of three key system components: abiotic drivers, ecosystem processes and biotic responses and feedbacks (Fig 1). In our case, the main abiotic drivers are (1) seasonal, annual and decadal variations in climate, (2) geomorphology, soil texture and depth, and surface hydrology, and (3) season and periodicity of fire. These abiotic drivers affect biogeochemical cycles, particularly nitrogen, phosphorus and carbon, as well as water input, storage, use and loss. Biotic responses to the coupling of these abiotic drivers and ecosystem processes include patterns and controls on net primary production, and the distribution, abundance, diversity and dynamics of plant and animal populations and communities. Although there is considerable research linking primary production and plant community structure, one of the core activities of the Sevilleta LTER is to link climate dynamics, disturbances, and soil structure with soil nutrient and water fluxes to better understand seasonal and annual variability in NPP and its impact on the dynamics, distribution and abundance of key aridland consumers, particularly small mammal populations, lizards and arthropods. Our research program is organized into five main research areas: Climate and abiotic drivers (Cliff Dahm, Group Leader), Soils and biogeochemistry (Bob Sinsabaugh, Group Leader), Water fluxes (Will Pockman, Group Leader), Producer dynamics (Esteban Muldavin, Group Leader), and Consumer dynamics (Blair Wolf, Group Leader). New and continuing research includes a wide variety of activities in each sub-area (Fig 1). This figure, along with our new conceptual framework on multi-scale pulse dynamics in aridland ecosystems, forms the basis of our upcoming renewal proposal. Many of the activities and findings in this annual report reflect our response to the 2003 Site Visit. Major recommendations of the site visit team included expanding and generalizing our conceptual framework, increasing our focus on belowground processes, getting more UNM faculty and graduate students involved in Sevilleta LTER research, and increasing our publication output. We have taken these recommendations seriously and we hope this report reflects our response to the review team's major recommendations.

Fig. 1 Current, New and Planned Sevilleta LTER Research Activities



The Sevilleta LTER Program was particularly active during 2004-2005. During the past year we continued our long term observational studies and manipulative experiments, and we added several new, important observational sites and experimental projects. These activities are briefly outlined below in two sections, Continuing Activities and New Activities. Outcomes of some of these activities are highlighted in the "Findings" section.

Continuing Activities: In the area of **climate and abiotic drivers** we continued to maintain a network of seven comprehensive meteorological stations across the Sevilleta National Wildlife Refuge. In addition, we are now a site in NOAA's Climate Reference Network. Finally, the Sevilleta LTER is serving as a test site for the development of intelligent wireless sensor networks for ecological monitoring, in this case monitoring of microclimate under different species of native shrubs (See Findings). In addition, we received funding from NSF-Ecology (Fargione, Collins, Pockman, PI's) to start a new climate manipulation experiments at the Sevilleta that will determine experimentally the effects of increased nighttime temperatures (especially in winter), increased El Nino events, and increased N deposition on interactions between three dominant species, blue grama, black grama and creosotebush. Also, we just completed installation of infrastructure to allow us to manipulate precipitation pulses (size and interval between events) that will allow us to control, to some extent, precipitation, the key driving variable in aridland ecosystems. This will compliment a recently funded experiment (NIGEC, Pockman and Small, PI's) to increase precipitation inputs by 50% adjacent to the existing rainout shelters that reduce precipitation by 50%.

In the conceptual area of **biogeochemistry and soils**, we continued to measure root and mycorrhizae dynamics in an N-fertilization experiment established in 1995 as part of a cross-site study to determine the effect of N deposition on mycorrhiza-plant interactions. Twelve of the 20 plots had minirhizotrons installed several years ago and we continue to take seasonal readings in these minirhizotrons each year. We continued our monitoring of bulk nitrogen deposition at 11 sites across the Sevilleta and wet-dry deposition at two sites. Soil microtopography and Nmin are sampled seasonally in recently burned (2003) and unburned grassland. We have continued fertilizer applications in our long-term N-fertilization experiment (see also New Activities, below). Finally, we continue to maintain three eddy covariance flux towers (in riparian forest, upland grassland and creosote shrubland) at the Sevilleta. These towers measure CO2 and ET fluxes at each site.

We continue to measure soil water dynamics and ecosystem level **water fluxes** in riparian, grassland and shrubland areas of the Sevilleta via numerous soil moisture probes at the Very Intensive Moisture Array site and the rainout shelter plots located in creosotebush, transition and grassland areas, and at three ET flux tower sites in riparian forest, grass and shrub-dominated areas. We will continue to remove 50% of ambient rainfall in replicated plots in grassland, shrubland and transition areas to induce drought and assess the impacts of severe drought on plant physiology and various ecosystem processes (Fig 2). In addition, our new rainfall pulse, 50% water addition and nighttime warming experiments will add to our general understanding of soil water dynamics and ecosystem processes.

Fig 2. Rainout shelters in creosote-dominated shrubland. Similar shelters are located in black grama dominated grassland and in a grass-shrub transition zone. Water addition plots are located behind the rainout shelters.

In the area of **producer dynamics**, we continued to measure vegetation composition and structure along two 400-m long permanently located line intercept transects on McKenzie Flats. Data from 1989-2003 were analyzed and presented by Collins et al. at the 2004 ESA Annual Meeting in Portland, OR. In addition, we continued to measure vegetation composition along four 100-m long permanently located line intercept transects that cross a burned-unburned boundary from a wildfire in 1995. We continue to measure plant community composition in grassland and shrubland areas with and without rodents (See Findings), and we continued to maintain and measure plant species and functional group removal experiments (See Findings). In addition, we measure ANPP at our core blue grama, black grama and creosote sites, and we measure belowground root and mycorrhizae dynamics in minirhizotrons in the N fertilization experiment, mixed grass-dominated vegetation near Deep Well, creosote-dominated vegetation near Five Points, mixed grass-shrub vegetation in the rainout shelters, and under fertilized and unfertilized piñon and juniper trees in the Los Piños Mountains.

Continuing measurements of **consumer dynamics** include small mammal and arthropod pitfall traps in blue grama, black grama, creosote, and piñon-juniper sites, and grasshopper populations in grassland, grass-shrub transition and shrub-dominated sites. We also monitor coyote and rabbit abundance on McKenzie Flats. One of the unique activities of the Sevilleta LTER is our long-term monitoring of native bee populations in desert grasslands spearheaded by the head of our field crew, Karen Wetherill, in collaboration with Burt and Rose Pendleton of the USFS Rocky Mountain Research Station in Albuquerque.

New Activities: In the area of **climate and abiotic drivers** we will be installing a new Sensor Web 5.0 network to monitor microclimate variation in our new nighttime warming, El Nino, N-deposition experiment funded by NSF-

Ecology and EPSCoR. Sensor Web 5.0 is a much improved system of wireless sensors developed by Kevin Delin and colleagues at NASA's Jet Propulsion Lab. Wireless sensor networks are not passive dataloggers without wires, instead, they can be programmed to perform QA/QC and activation algorithms, among other duties, on the fly (See Findings). The new experiment where we will install the Sensor Web 5.0 is designed to manipulate key climatic drivers that will ultimately affect microclimate, precipitation and soil moisture dynamics and nutrient availability in a system that is chronically low in water and nitrogen. This experiment links with producer dynamics in that it is designed to determine if predicted changes in rainfall, nitrogen and temperature will increase the rate at which woody vegetation, particularly creosotebush, will invade and eventually replace grass-dominated vegetation.

Water fluxes: Using start-up funds provided by UNM to PI Collins, we are installing a replicated field experiment that will allow us to control the size and frequency of monsoon rainfall pulses in desert grassland. Treatments will include ambient rainfall (reference plots), and plots which receive (1) one large rainfall event each month, (2) two medium-sized rainfall events each month or (3) small, weekly rainfall events. Each of the three rainfall addition treatments will receive the same amount of total rainfall by the end of the monsoon season (July-Sept). Subplots in each treatment plot will receive N fertilizer at a rate of 5gNm-2 in two 2.5g applications each year to allow us to determine how rainfall pulses interact with N dynamics to affect soil C fluxes, community composition and annual aboveground NPP. This experiment is co-located with, and will compliment data from, existing infrastructure that either removes 50% ambient rainfall from replicate plots or increases ambient rainfall by ca. 50% each year (Fig 2).

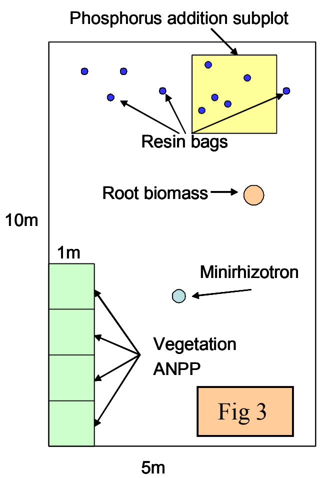


Fig 3

Biogeochemistry and soils: We have greatly enhanced our research activities in our long-term N-fertilization plots (Fig 3). In 2005, we received "proof of concept" funding from NSF-Ecosystems (Sinsabaugh, Collins, Allen, Hanson, PI's), to investigate the role of fungi in the N cycle of these arid grasslands (See Findings). In addition, we now measure plant species composition, above- and belowground NPP, N and C availability, and extracellular enzyme activities in treatment and control plots. We have also added P-addition subplots within the N fertilization plots so that we can determine the relative roles of N and P in this aridland ecosystem. Increasing our activities in these plots allows us to tie into an important LTER cross site synthesis of fertilization effects on plant community structure and dynamics (Suding, Collins et al. 2005, Pennings et al. 2005). Bryan Brandel, a graduate student at the University of Colorado, is studying N and C dynamics across the grass- to shrubland ecotone. This work will allow him to use remote sensor to scale up N and C processes at the Sevilleta. In addition to our nutrient amendment experiments, two graduate students from the Department of Earth and Planetary Sciences at UNM started to characterize the geology and geomorphology of the McKenzie Flats area, one of our main study areas at the Sevilleta, using a series of deep soil trenches (See Findings).

Producer dynamics: In 2004-5 we initiated collection of plant species composition in 48 permanently located quadrats in two experiments that were initially established in 1993 but lacked consistent vegetation collection protocols. The first experiment addresses the effect of grazing on plant community dynamics in desert grassland. Three replicate 300x300m exclosures were established in a grazed pasture north of the Refuge boundary. These exclosures were paired with three sample areas open to grazing by domestic cattle. In addition, there are three similarly sized sample areas inside the Refuge boundary. This allows us to measure the short-term and long-term recovery dynamics of grasslands following grazing by domestic cattle. Soil N dynamics and standing crop are also measured annually in each treatment. In 2004 we also initiated a similar sampling protocol in another experiment with and without browsing by native antelopes. This experiment has four replicates of the following treatments burned in 2003 or left unburned, fully crossed with open to antelope browsing versus no antelopes.

In 2004-5, we expanded our NPP measurements from only three core areas to ten sites, including burned and unburned grassland, transition, and creosote-dominated shrubland. We also resumed NPP measurements in the herbaceous layer in Piñon-Juniper woodland at Cerro Montosa. Because our NPP measurements are based on non-destructive allometric estimates by species (same as Jornada LTER), we also get accurate long-term measurements of plant community composition at our NPP sites. We added a new sampling protocol in which we now measure belowground standing crop at all sites where we measure aboveground production. In addition, we installed root ingrowth donuts at five sites co-located near minirhizotron arrays as well as in the N-fertilization plots.

Joanna Redfern (graduate student) in collaboration with **Burt Pendleton** (USFS Ecologist) and **Etsuko Nonaka** (graduate student) are in the process of mapping populations of creosotebush (*Larrea tridentata*) and ocotillo (*Fouquieria splendens*) for long term studies of plant population dynamics at the Sevilleta. Nine 20m^2 plots have been established to monitor creosotebush near the Five Points area. The design includes three sets of three plots, where each set of plots includes a low, medium, and high density plot. All of the low and medium density plots and one high density plot have been surveyed this year to determine the number of plants in the plots, and the exact location of each plant within the plot. Three plots (low, medium and high density) were established to monitor ocotillo population dynamics. The steep rocky terrain on which ocotillo grows precludes using the same technique as is used to survey creosotebush plants. GPS will be used to survey ocotillo within these plots. A system to convert the raw location data for each plant in a plot into a stem map for the plot is being developed. For the demographic study of ocotillo size classes (i.e. small, medium, large) are being identified to identify which plants to use to relate size to biomass. The size classes are based on height measurements made in 2003.

Consumer dynamics: In 2005 we initiated an exciting new experimental restoration of Gunnison's prairie dogs at the Sevilleta. Through the hard work of Sevilleta staff and graduate students in partnership with USFWS, private foundations, and a prairie dog restoration specialist, 99 artificial burrows were constructed at the SEV to create three replicate prairie dog colonies with approximately 110 animals added to each new colony. Each replicate colony is paired with a prairie dog-free reference area. Planned long term measurements include plant species composition, above- and belowground standing crop, soil nutrient dynamics and, of course, prairie dog population dynamics.

Soil excavation for artificial prairie dog burrows at the Sevilleta National Wildlife Refuge as part of our new Gunnison's prairie dog restoration experiment. Ninety-nine burrows were excavated by backhoe. A total of 327 prairie dogs was introduced in three replicate colonies on the north end of McKenzie Flats.

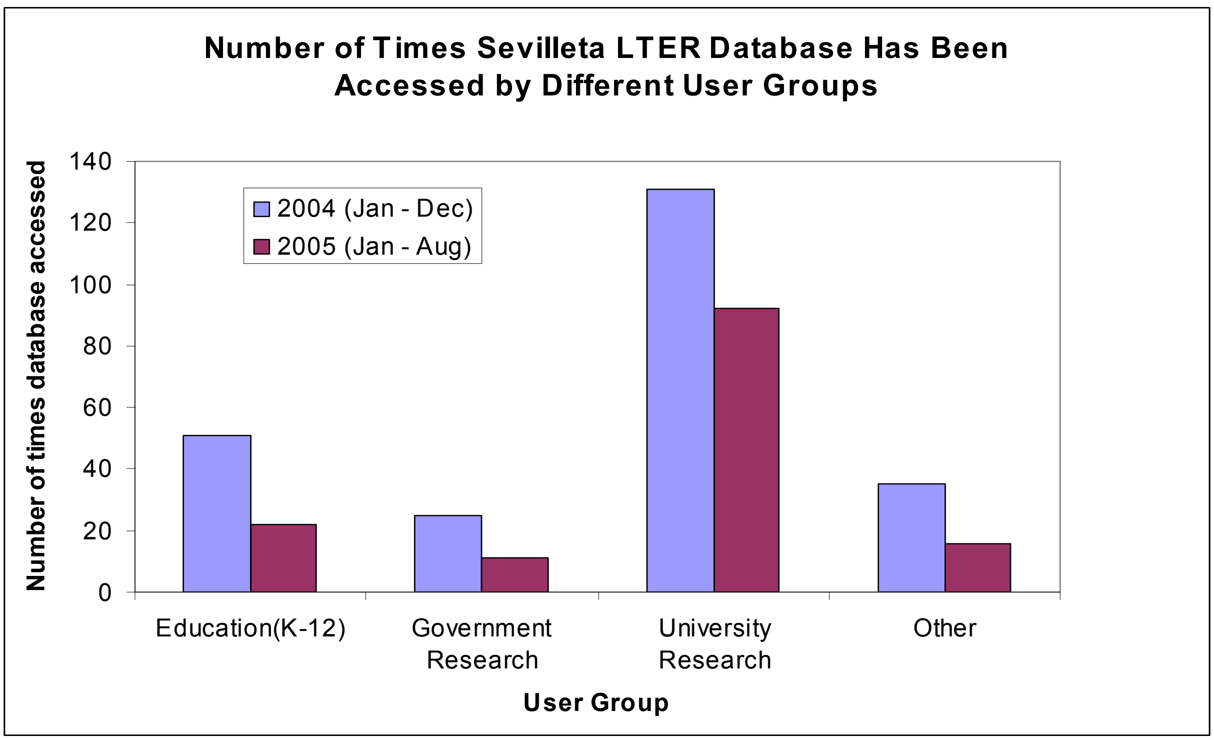
In addition to our restoration experiment, **Megan M. Friggens**, a graduate student at Northern Arizona University, is studying plague ecology of Gunnison's prairie dog to determine if a rodent mediated mechanism exists for plague epizootics. This project is designed to assess whether climate driven-dispersal events of plague (*Yersinia pestis*) reservoir hosts cause plague epizootics in Gunnison's prairie dog (*Cynomys gunnisoni*) colonies. In particular, we examine the relationships between weather patterns (precipitation), vegetation production, rodent and flea densities, prevalence of pathogens within host and vector, and interspecific contact between potential rodent carriers and the prairie dogs inhabiting the Sevilleta National Wildlife Refuge. Another vector-transmitted blood-borne bacterium, *Bartonella,* is also being surveyed from the small mammals captured in this project. *Bartonella* are generally less pathogenic and more frequently (often >50% prevalence) found in their mammal hosts than *Y. pestis.* Thus, *Bartonella* will be used to study interspecific transmission dynamics in the potential absence of plague outbreaks on the Sevilleta. Though several rodent species have been implicated as potential reservoir hosts of plague, no research has assessed the role of these potential reservoir species or their fleas in introducing plague into prairie dog colonies. Since May 2004, surveys have been conducted each spring and fall of the rodents inhabiting a prairie dog town on the Sevilleta and blood and flea samples have been collected from each animal to test for the presence of plague and *Bartonella*.

Tim Meehan (former graduate student and now an Assistant Professor at College of Santa Fe), **Blair Wolf** (LTER-CoPI) and **Casey Gilman** (REU) are in the process of studying carbon and nitrogen turnover in lizard tissues in relation to their metabolic rates. Lizards are important secondary and tertiary consumers in Southwest ecosystems. Stable isotope analysis of lizard tissues can be used to understand the specific roles of lizards in material and energy flux. Interpreting stable isotope data on lizard resource use requires an understanding of isotopic fractionation factors and turnover rates. A diet switching experiment is being conducted to learn how these quantities are related to individual metabolic rate, which is in turn related to an organism's body mass and temperature. This project is still in progress and is expected to continue until spring of 2006. To date, lizards have been collected, housed, and fed a baseline diet with a known isotopic profile. The next step is to switch their diet to one with a different isotopic profile and make a series of measurements of carbon and nitrogen isotopes in their tissues. The diet switch occurred in summer 2005.

In a related study, Graduate students **Alaina Pershall** and **Robin Warne** and CoPI **Blair Wolf** are using stable isotopes to study foodweb dynamics in the creosote-grassland transition zone near Five Points at the Sevilleta. They sampled rodents, lizards, arthropods and vegetation for stable isotope analysis of carbon and nitrogen. Because C3 and C4 plants have growth responses during different seasons, we expect to see a shift in the carbon isotope signal of the sampled organisms reflecting the changes in the vegetation from C3 plants in the spring to C4 in the fall. Twelve pitfall trap arrays with drift fencing were installed this summer for catching lizards, and small mammals were sampled monthly on two rodent trapping webs. All arthropods found in the pitfall traps were collected and grasshoppers were also collected with nets and will be processed for stable isotope analysis. Blood samples from lizards and rodents were collected monthly for stable isotope analysis. This work will continue through 2005 and 2006 growing seasons. Results of the stable isotope analyses are pending.

Information Management

With the assistance of Inigo San Gil of LNO, approximately 40% of the Sevilleta LTER's legacy metadata has been converted into Level 3 or better Ecological Metadata Language (EML), the LTER Network's metadata standard. Sevilleta EML files are being harvested to a centralized Metacat database (http://prairie.lternet.edu:8080/query). This will greatly facilitate the discovery of Sevilleta data.



Updates to the Sevilleta LTER website include the addition of a Wiki to the Intranet, where an IM Handbook is being created. Webmail is now also available via the Intranet, as is an interface where researchers log their visits to the Sevilleta NWR.

The Sevilleta LTER bibliography database was transferred from a text file to the Sevilleta MySQL database. A web application was also created by programmer Harsha Belludi for searching the Sevilleta bibliography and adding new records.

A much-needed backup system for the Sevilleta Sun E450 server was installed in January 2005.

Extracurricular activities:

Kristin Vanderbilt, Sevilleta IM, has served as information management liaison to the Biogeochemistry Committee for the Network Planning Grant. She contributed a poster entitled: "Ecoinformatics Training: Toward Data Sharing and Collaborative Research" to the NSF sponsored workshop "Enhancing Collaborative Research on the Environment in Sub-Saharan Africa (SSA)". Kristin also co-organized a panel discussion at the 2005 Statistical and Scientific Database Management (SSDBM) meeting (Cushing et al. 2005). She is collaborating on a research project with Judy Cushing of Evergreen State College wherein templates for grassland NPP databases are being developed to facilitate data synthesis across LTER sites. Kristin co-taught a week-long ecoinformatics workshop for personnel from the Organization of Biological Field Stations (OBFS), an annual event. As a collaborator on the Science Environment for Ecological Knowledge (SEEK) project, Kristin also co-taught an ecoinformatics workshop for post-docs and junior faculty.

The Sevilleta Research and Education Center, Sevilleta National Wildlife Refuge, New Mexico. A consortium of UNM, NM Tech, NMSU, Sandia and Los Alamos National Labs have integrated and focused their research efforts to address important environmental issues in the state and integrate this research with public education over a broad range of disciplines. A key to the success of this effort is the addition of a Research and Education Center to the Research Field Station on the Sevilleta National Wildlife Refuge (NWR) in Socorro County, New Mexico. *The location in central New Mexico and in the natural environment of a wildlife refuge is key to providing a common base to attract and organize researchers and educators from throughout the state and Southwest Region.* Scientists, resource managers and students from many disciplines will use the facility to plan and carry out multi-disciplinary studies throughout the Rio Grande Valley of New Mexico. Center research capabilities will include laboratories for plant and animal studies, soil and water analyses, genetic studies, microbial research, biodiversity mapping, and infectious disease research. Access to state-of-the-art high performance computing and data management will allow integration of myriad databases generated by Federal, State and University researchers. This integration is needed for the successful incorporation of our scientific understanding to natural resource management activities. There are many independent data generating activities within the state but they are *not* well integrated. Teaching and public outreach facilities will disseminate the information to K-12 students and the general public. The new Center will contribute to:

- **Scientific research for multi-disciplinary projects** – The Sevilleta NWR currently hosts many active research programs and this new facility will allow the needed expansion of research required to better understand environmental issues throughout the broader Rio Grande Basin. These studies will lead directly to "applied" results for society – for example, predictions of human disease outbreaks (hantavirus, plague) based on ecosystem responses to El Niño weather patterns, improved hydrologic data for the Rio Grande that will aid policies on water allocation, habitat needs for aquatic and riparian species (e.g., Silvery Minnow, Willow Flycatcher), and estimating agricultural, range and timber production from satellite-based spectral sensors. New technologies in remote sensing will allow real-time mapping of changes in these patterns and rapid-response capabilities. This also will allow testing of new technologies developed by university and national lab research.
- **Research on management issues involving public lands** – Land management strategies will continue to evolve as social pressures on public natural resources increase. Researchers in the Rio Grande Basin of New Mexico need to work together to address the complexities of human activities and economic development on natural resources and ecosystem health. Given the Sevilleta NWR's history of environmental research and its central geographic location in the New Mexico's Rio Grande Basin, the refuge is ideally suited to become a central hub for research on such topics as range and wildlife management, conservation strategies for endangered species, removal of problem species (e.g., salt cedar), human land use patterns, fire ecology, and ecosystem responses to climate change.
- **Attracting world-class scientists** – Hundreds of scientists/students have been attracted to the science conferences and research capabilities on the Sevilleta NWR over the past decade. This will increase with the new facility and add markedly to the expertise and information available for resource managers, policy-makers and educators. The capabilities also attract other agency research efforts (e.g., NASA validation studies for satellite sensors, ARS research on fire).
- **Public dissemination of research results** – Much of the data generated by government and university researchers remains inaccessible or incomprehensible to the general public. Researchers at the Sevilleta Center would integrate these data, and make them available for public groups and individuals. The Sevilleta NWR has functioned as "neutral ground" for opposing public interest groups (environmentalists to ranchers), and the

expanded Center's facilities will enhance the role of the consortium of institutions in providing a rational scientific basis in public debates on issues of public importance in New Mexico. Conferences at Sevilleta also provide a "neutral ground" atmosphere.

- **Public education** – The proposed Sevilleta Center will provide vastly expanded educational opportunities for K-12, undergraduate and graduate students, and science training opportunities for teachers. Involving students and teachers in research "*in the field"* is critical to the success.

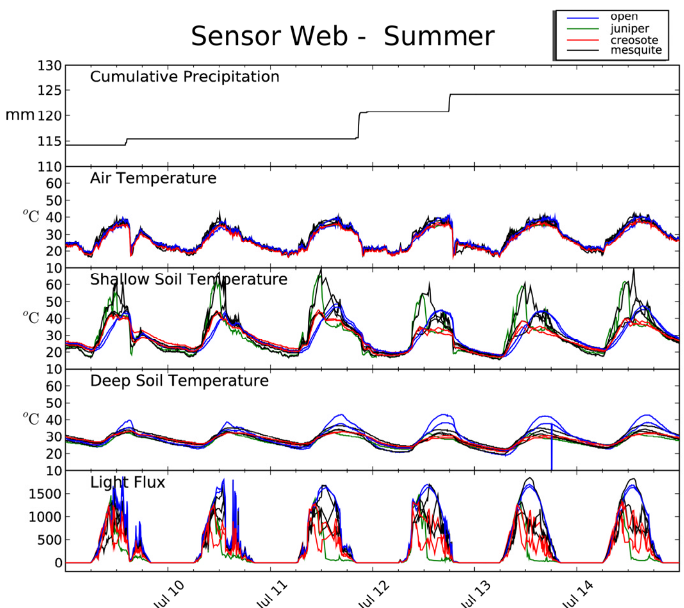
UNM Sevilleta Field Station SMPC Architects

FINDINGS

Climate and abiotic drivers

Fig. 1. Sensor Web 3.1 pod underneath a juniper tree.

Scott Collins (Sev PI), **Renee Brown** (Sevilleta Systems Administrator), **Doug Moore** (Met Central Czar) in collaboration with **Kevin Delin** and his team at the Jet Propulsion Lab (JPL), and **Luis Bettencourt**, **Aric Hagberg** and **Levi Larkin** of Los Alamos National Labs (LANL) are developing data analysis and QA/QC protocols for wireless Sensor Web enabled microclimate monitoring for ecological research (Palmer et al. 2005). Specifically, we are using Sensor Web 3.1 to address the question, are all resource islands equal? A fundamental concept in arid land research is the development of island of fertility under woody plants as desertification occurs. However, it is not clear that all such islands are ecologically equivalent. In fall 2003 we installed 12 Sensor Web pods in a study area near the Sevilleta Field Research Station to measure microclimate variables in three open areas, and under three individuals each of creosotebush, juniper, and mesquite (Fig 1). Sensor Web 3.1 pods record the following microclimatic variables every ten minutes: soil temperature (2 depths), soil moisture, air temperature, relative humidity and light. The collaborators from LANL are developing data extraction and QA/QC protocols for analyzing large streams of wireless sensor data. In particular, the group is developing QA/QC algorithms that can be embedded in the Sensor Web network to identify outlier data points on the fly.



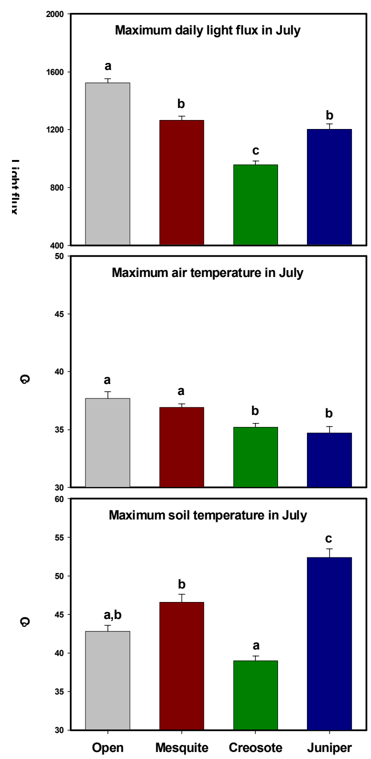


Fig 2. Example of data streams for a five day period in July 2004 (above). Statistical analysis of maximum daily light flux, maximum daily air temperature and maximum daily soil temperature for July 2004 in open areas and areas beneath three shrub species at the Sevilleta (right).

Results indicate that there are significant differences in microclimate under each species leading to greater resource heterogeneity in aridland ecosystems. An example data output stream from the Sensor Web is shown in Fig. 2). Differences in summer light flux beneath species are evident, both in maximum light

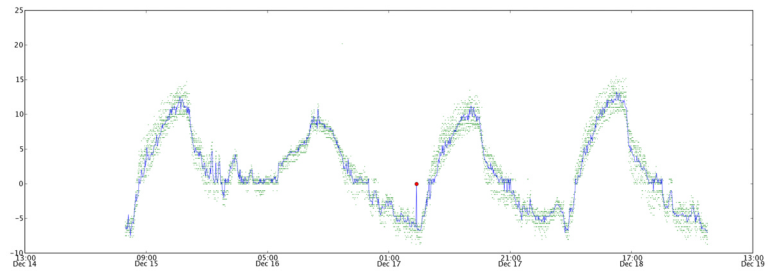


Fig 3. Example of QA/QC procedure. The blue trace is Air Temperature from Pod 12 and the Green Points are from a neighboring pod. The red point by itself is within the regular range of data points, but is out of range for the measurement period (>3 standard deviations away from neighbors [99% CL]. Error detection algorithms can be embedded into the Sensor Web network to detect and flag odd data values.

levels and time of day at which light levels peak. Also, fluxes in deep soil temperatures are generally greater in open areas compared to that under shrubs. Surprisingly, July maximum soil temperature was highest under the evergreen juniper (Fig 2). This occurs, most likely, because juniper litter and organic matter darken the soil such that a greater heat load is transferred to shallow soil depths in the summer time. QA/QC procedures are being developed based on the following premises: (1) environmental data are usually non-stationary because of diurnal, seasonal and annual cycles, (2) over short time frames data should be spatially and temporally coherent over neighboring sensors, (3) differences of commensurate measurements have statistics with bounded variances based on the central limit theorem, (4) because all Sensor Web pods share all data after every measurement, simple estimation methods (e.g. frequency estimation) can be used to characterize the mean and variance, (5) quality control can be implemented on the fly by excluding data points that have large differences to several neighbors, at some predetermined mean and variance (Fig 3). Once developed Sensor Web technology and embedded algorithms can be used to assess treatment efficacy within ecological experiments and eventually, actuation of experimental apparatus. Through our collaboration with JPL and LANL we are developing these algorithms in the context of newly NSF-funded project on the effects of nighttime warming, increased rainfall, and nitrogen deposition experiment at the Sevilleta. This work was presented by Collins et al. in an organized oral session on sensor networks for environmental research at the 2005 ESA Meeting in Montreal.

Water fluxes

Cliff Dahm (Sevilleta CoPI) and colleagues have been measuring rates of evapotranspiration (ET) in the riparian zone along the Rio Grande since 2000. Sites include a cottonwood dominated site with considerable amounts of non-native species in the understory that no longer floods (Albuquerque – SHK), a cottonwood dominated site that floods occasionally (Belen – BLN), a salt cedar and salt grass dominated site on the Sevilleta National Wildlife Refuge (Sevilleta NWR – SEV), a salt cedar dominated site at Bosque del Apache National Wildlife Refuge (Bosque del Apache NWR – BDAS), and a Russian olive and willow dominated site at La Joya State Game Refuge (La Joya SGR – LARO). Growing season ET at the SHK, SEV, and BDAS sites has been measured from 2000 – 2004, the BLN site was operational from 2000 – 2003, and the LARO site has made measurements from 2003 – 2004. Average annual growing season ET is highest in the SHK site with the mixed community of cottonwood overstory and a largely non-native understory. Average annual ET from the SHK site for 2000 – 2003 was 128 cm (± 4 cm). A partial restoration project involving the non-native understory species was begun in 2004. Annual ET in 2004 was 115 cm. The restoration project was completed in the winter of 2005, and annual ET estimates for the growing season of 2005 should help define the impact of this restoration project on overall riparian water use. Average annual ET from the BLN, BDAS, and LARO sites has been similar through the period of measurement (Fig 4). Average annual values for BLN, BDAS, and LARO have been 108, 106, and 112 cm, respectively. Standard error around the mean of these averages is greater at these sites compared to SHK. This reflects the greater interannual variability at these sites. For example, the average annual ET flux at the salt cedar dominated BDAS site has ranged from 88 to 119 cm. The lower values in 2002 and 2003 occur in years with complete drying of the Rio Grande and large draw downs in the water table during the growing season. Salt cedar, a facultative phreatophyte, adapts to the lowered water table by reducing transpiration and decreasing leaf biomass. The BDAS site is scheduled for a salt cedar eradication project in 2006, and this project will allow direct measurement of ET reduction from removal from a dense monotypic stand of

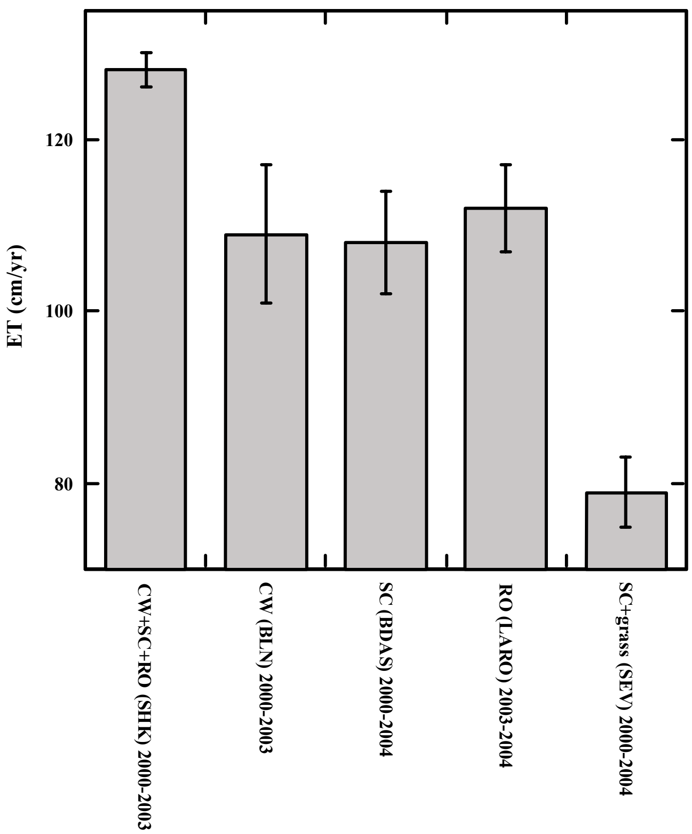


Fig 4. Annual ET (cm/yr) at five tower sites with differing types of riparian vegetation measured with three-dimensional eddy covariance instrumentation. The sites are in the riparian forest (bosque) along the Rio Grande in and adjacent to the Sevilleta NWR.

non-native vegetation. The SEV site has the lowest average rates of annual ET with an average for 2000 – 2004 of 79 cm (± 7). This non-flooding salt cedar and salt grass site is less densely vegetated with a relatively stable groundwater table due to a downstream irrigation diversion dam. Long-term deployment of eddy covariance equipment throughout multiple growing seasons has facilitated an excellent data base from which to evaluate water use by different types of riparian vegetation under differing hydrological conditions.

Biogeochemistry and soils

Debra Bryan (graduate student), **Carolyn Dumrose** (graduate student), **Grant Meyer** (LTER Senior Scientist) and **Les McFadden** (LTER Senior Scientist) all in the department of Earth and Planetary Sciences at UNM are studying deep soil structure and development on McKenzie Flats at the Sevilleta. During the spring and summer of 2005 soils and geologic media were exposed in four large (~11 m x 8m x >2 m depth) soil trenches constructed to OSHA safety requirements on McKenzie Flats. Two trenches were located approximately 3 km apart on an active alluvial fan of the granitic portion of the Los Piños Mountains. The northern-most fan trench study site is covered by C3 and C4 grasses (40%, *Bouteloua* and *Hilaria*), bare patches (29%), sand sage (22%), mormon tea (4%), soapweed yucca (1%) and cacti (1%). The southern-most alluvial fan site is dominated by C3 and C4 grasses (>60%), and also contains mormon tea, fourwing saltbush, soapweed yucca, and cacti. The southern-most trench has higher cover and few bare patches. Soils on both sites are polygenetic and are characterized by multiple depositional and erosional events followed by periods of quiescence leading to soil development. The lower-most exposed horizons are eroded, buried loamy soils exhibiting Stage III-IV calcic soil development indicating great age (several tens to hundreds of thousands of years). These buried soil horizons are overlain by multiple sandy fan deposits with clasts ranging from a few millimeters to several tens of centimeters in diameter. Some fan deposits exhibit incipient soil development but most are unaltered alluvium derived from the processes of erosion and deposition associated with fan development during wetter climatic periods. The lack of significant soil development indicates that these deposits are quite young (few thousands of years) and/or that they have been too disturbed to form soil horizons. Overlying these more clast-rich deposits are modern soils derived from sheet wash (coarse sand, pebbles, and few small cobbles) and eolian fine sand and silt. The modern soils exhibit “A” horizons (darkened by organic matter) and weak “B” horizons (some evidence for elluviation and formation of soil structure), and are likely a few hundred to a few thousand years old. The context of fine grained soils derived from sheet wash overlying cobble to boulder-rich fan sediments, is affecting water infiltration in the upper 0 – 30 cm of the subsurface. In the southern-most trench, some infiltrating waters have evaporated (depositing soil carbonate) prior to moving around boulders contained within the upper 13 cm. In the northern-most trench, the same observations were made for the upper 25 cm. The context of more permeable sediments overlying less permeable soils and sediments at depth may also be affecting soil hydrology: coarse and fine mormon tea and sand sage roots were observed exiting the face of the trench and traveling laterally for some distance before moving downwards. These observations were most often made at horizon boundaries with permeability contrasts in which the overlying sediments were more permeable than the underlying sediments. Water at these boundaries may temporarily "pond" as the process of infiltration begins to slow due to the decrease in permeability. Mormon tea and sand sage roots were found at 90 – 140 cm below the surface in the northern-most trench and mormon tea roots were found at 173 cm depth in the southern-most trench. The depth of root penetration also appears to be correlated to permeability as determined by clast size, clast sorting and the grain size of the matrix.

The remaining two trenches were located on a topographic high bounding the south-western extension of McKenzie Flats. This topographic high is probably a remnant fan surface formed by the Paleo-Palo Duro Wash approximately 800 – 900 Ka. The western-most trench is located near the Five Points Road intersection and is dominated by creosotebush (>75%) and barren patches of land. Some grama grasses are also present, but in small amounts. The lower-portion of the western-most trench contains several fluvial and sheet wash deposits (approximately 80 cm thick) that are nearly completely plugged with gypsic cements. The clasts contained within the lower-portion of the trench include gypsiferous limestones from the Yeso Formation, and are likely the source of the gypsic cements in the surrounding sediments. Immediately above these deposits is a thick (~90 cm), fine-grained, Stage IV+, petrocalcic soil horizon with large (filled) animal burrows and many pisolites. The presence of a laminar, brecciated and massively cemented petrocalcic horizon again indicates great age. The pisolites within this horizon are pebble-sized and contain multiple inner coatings of tan colored cements and one thin outer coating of soil carbonate. Above the surface of the petrocalcic soil is an erosional surface overlain by the modern soil. A thin (13 cm) horizon of unaltered fluvial sand, ripped up carbonate chunks, and eolian silt separates the modern soil from the underlying petrocalcic horizon. The modern soil is 18 cm thick and is derived from ripped-up soil carbonate chunks from the underlying petrocalcic horizon, fine grained sheet wash, and eolian silt. Coarse and abundant creosotebush roots were observed in every horizon, or pocket of sediment, not completely plugged by gypsic cements. This observation indicates that the gypsic cements are chemical or physical barriers to creosotebush roots, or both. Grass roots were observed in the modern soil only. A lens-shaped charcoal deposit was found in contact with the petrocalcic horizon and below the modern soil. This deposit has been sampled for radiocarbon dating.

The eastern Five Points trench is located on a broad, shallow drainage incising the old Paleo-Palo Duro fan deposit and is approximately 0.9 km to the southwest of the other Five Points trench. The most striking feature of this trench is that, despite the fact that it is over 2 m in depth, it is nearly uniformly composed of fine sand and eolian silt. Also, in contrast to all other trench sites, nearly all of the soil horizons are reddened and exhibit clay films (evidence for translocated clay and argillic soils). Like the western Five Points trench, the lower portions (lower four horizons) contain gypsum cements. However, very few Yeso Formation clasts (or any other clasts) were observed in the trench, so the source of the gypsum cements was not immediately determined. The vegetation cover at this trench site is mixed and typically co-dominated by grama grass, creosotebush and bare patches. The cover immediately above the trench was slightly more dominated by grama grass. Creosotebush roots exposed in the trench were not observed below the first clay-rich calcic horizon (~31 – 58 cm). Grass roots were thick in the upper horizons and helped to hold the vertical trench faces. To increase spatial representation of soils, additional trenches and soil cores will be examined in late 2005 and 2006.

Selene Baez (graduate student), **Joe Fargione** (postdoc), **Doug Moore** and **Scott Collins** analyzed our long-term atmospheric N deposition data. In southwestern North America, N deposition has increased steeply in the last two decades due to the rapid growth of urban areas, and to an increase in agriculture and animal production. Recent evaluations of the rates and patterns of N deposition show that areas located near large urban centers are more prone to receive high amounts of atmospheric N. However, for most major cities in the southwest, the actual magnitude and temporal trends in these effects are unknown. The limited available evidence suggests that N deposition in arid ecosystems could stimulate plant growth, but that such responses are often strongly limited by water availability. However, most such studies to date have been short-term N fertilization experiments that often use N addition rates significantly higher than current rates of atmospheric N deposition. Our study examined long- term data on N deposition and net primary productivity on desert grassland vegetation in the northern Chihuahuan Desert. We quantified the rates of N

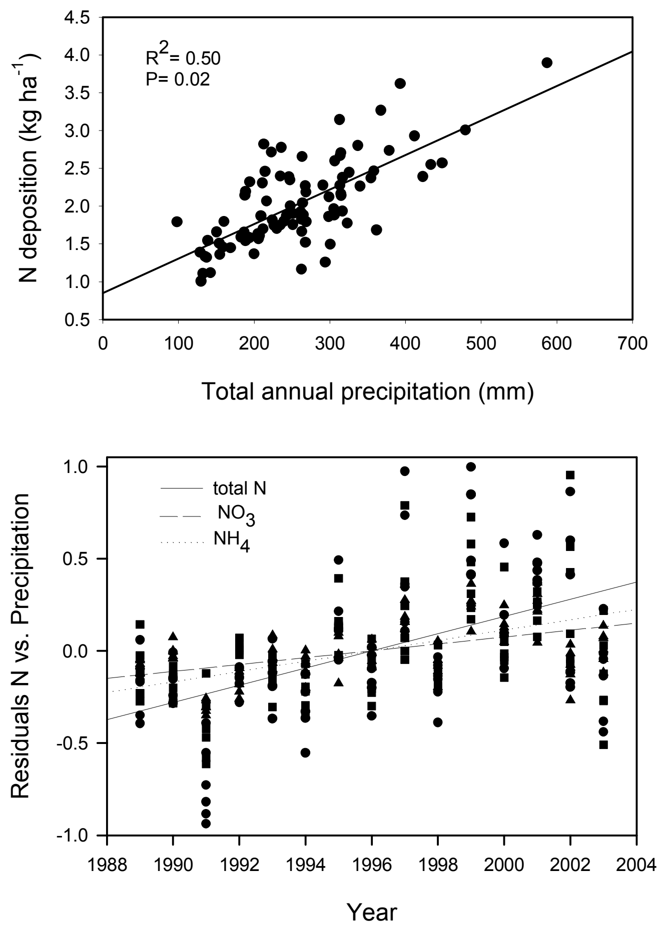


Fig 5. Linear regression of annual N deposition against precipitation (a). Linear regression of the residuals of total N, NO3 and NH4 versus annual precipitation (b). In both analyses each regression line was calculated with N=90.

deposition in native Chihuahuan Desert grass- and shrub-dominated plant communities and assessed the potential effects of N deposition on plant production and community composition in an ungrazed desert grassland community.

Nitrogen deposition was measured between 1989 and 2003 in a network of 6 funnel precipitation collectors located throughout the Sevilleta. These funnels collect all N deposited in precipitation (wet deposition) and any dry deposition that lands on or is washed into the sample. NO_3 and NH_4 were measured using a Technicon Auto-analyzer II and Dionex D-100 Ion Chromatograph that have comparable precision.

The amounts of total N deposited were positively related to precipitation volume (Fig 5). Total N, NO_3, and NH_4 deposition significantly increased from 1989 to 2003 (Fig 5). Total N deposition increased at a rate of 0.047 kg N ha^{-1} yr^{-1}, which corresponds to an annual increase of 2.3% of the long-term average annual deposition of 2.04 kg N ha^{-1}. Therefore, over 15 years of study, the Sevilleta has received 5.6 kg ha-1 of additional N that would not have been deposited if rates had not increased.

Deposition of NH_4 and NO_3 was positively correlated ($R^2 = 0.73$, $P < 0.0001$, $N = 90$). Over the years of the study more N was deposited as NH_4 (55.9%) than as NO_3 (44.1%), and the rates of deposition increase were non-significantly higher for NH_4 (0.028 kg ha^{-1} yr^{-1}) than for NO_3 (0.018 kg ha^{-1} yr^{-1}, $P = 0.19$ for *t* test of the slopes). The seasonal deposition rates of total N, NO_3 and NH_4 were higher during the summer than during the rest of the year. On average, 46% (0.93 kg ha^{-1}) of the annual N deposition occurred during the summer months. Furthermore, the proportion of N deposited annually during the summer months was positively related to total annual precipitation (Linear regression, R^2=0.12, P=0.001, N=90).

We are still analyzing the long-term relationships between N deposition and net primary production. Nevertheless, N deposition has increased in the Chihuahuan desert in central New Mexico from 1989 to 2003. The observed rate of N deposition, although low in comparison with regional estimates, is increasing. In this ecosystem N deposition maintains constant seasonal patterns related to precipitation. The increased rate of N deposition may not effect ANPP dramatically, but an on-going N fertilization experiment at our site suggests that chronic N deposition will eventually result in higher net primary production and potentially a decrease in legume abundance, a key plant functional type, as has been found across a number of sites in North America (Suding, Collins et al. 2005).

Bryan Brandel, a graduate student with **Carol Wessman** at the University of Colorado, is conducting his dissertation research (Scaling Ecosystem Processes in a *Larrea tridentata* Ecotone: The Influence of Landscape Structure on Ecosystem Function) at the Sevilleta. Woody plant encroachment has occurred in arid and semiarid grasslands worldwide, including the grasslands of the southwestern United States. At the Sevilleta National Wildlife Refuge (NWR) located in central New Mexico, creosotebush (*Larrea tridentata*) has replaced black grama (*Bouteloua eriopoda*) dominated semiarid grasslands along the Chihuahuan Desert biome transition zone. The mechanisms and consequences of woody plant encroachment are uncertain and complex and they have important implications for the functioning of semiarid ecosystems. The general goals of Bryan's research are to assess carbon and nitrogen storage and fluxes in relation to woody plant expansion in semiarid grassland and to utilize remote sensing to scale ecosystem transition processes to the landscape level. In 2003, four 50 m by 50 m plots in a line perpendicular to the shrub-grass transition boundary were established in each of three landscapes at the Sevilleta NWR near Five Points. Shrubland and grassland plots were established in the pure vegetation types while the middle two plots were located in the transition area and defined by relative shrub and grass covers. At random points within each plot, samples were collected beneath the nearest shrub patch, the nearest clump of grass, and the adjacent bare soil interspace. Soil organic carbon and total soil nitrogen to 20 cm depth were measured in the summer of 2003. *In situ* net nitrogen mineralization rates to 10 cm depth were measured for four periods during May to October 2004 and monthly during the 2005 growing season.

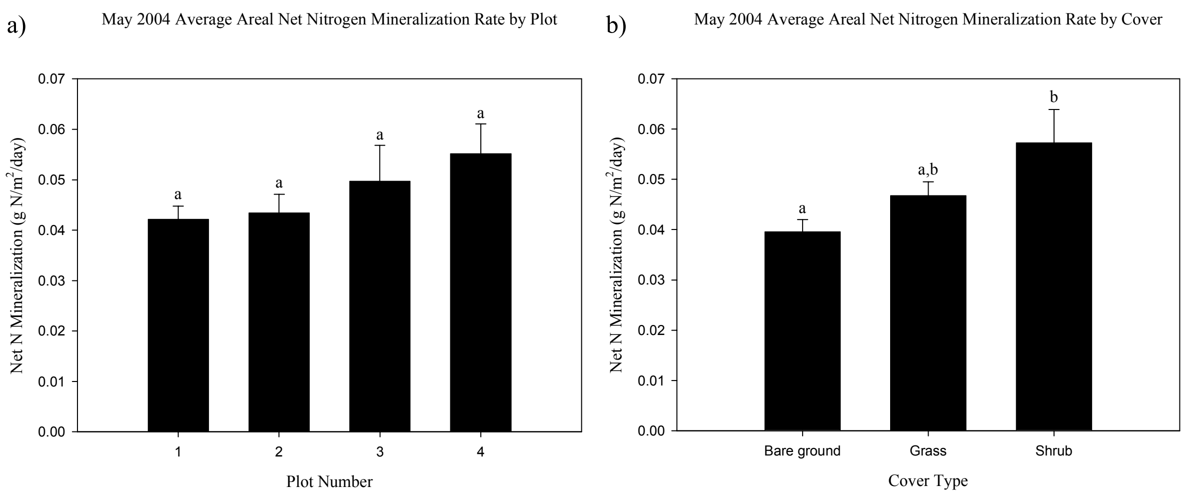


Fig 6. Average (+/- s.e.) net nitrogen mineralization rates by plot (a) and cover type (b) for May 2004 (n=153). Letters above the bars indicate significant differences at P<0.05l. (a) There were no significant differences in net nitrogen mineralization between plots (plot 1 is pure shrubland, plots 2 and 3 are located in the transition area, and plot 4 is pure grassland). (b) Average net N mineralization under shrub canopies was significantly greater than average net mineralization in bare ground areas.

In situ net nitrogen mineralization rates measured in May 2004 show significant differences for cover type, but not plot (Fig 6). Although there appears to be an increase in average net nitrogen mineralization across the transition from pure shrubland to pure grassland, these differences were not significant (Fig 6a). Average net nitrogen mineralization under shrubs (0.057 g N/m^2/day) was significantly greater than the average rate in bare ground (0.040 g N/m^2/day), while the average rate in grass (0.047 g N/m^2/day) was intermediate (Fig 6b). These preliminary results for *in situ* net nitrogen mineralization suggest fractional cover is the only information necessary for scaling nitrogen mineralization across the transition area to the landscape level. However, preliminary results for soil organic carbon and total soil nitrogen show significant differences due to plot and cover type. Thus, scaling these ecosystem properties to the landscape level requires considering both cover type and landscape position. Remote sensing analysis of aerial photography and NASA's Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) data will be used to determine fractional cover of shrubs, grass, and bare ground across the transition area. Fractional cover will then be used to scale field measurements including *in situ* net nitrogen mineralization rates, total soil nitrogen, soil organic carbon, and aboveground biomass carbon to the landscape level.

Bob Sinsabaugh (LTER Senior Scientist), along with graduate students **Chris Lauber, Marcy Gallo, Martina Stursova**, and **Andrea Porras-Alfaro**, and undergraduate students **Kylea Odenbach, Kendra Pitts**, and **Armida Carbajal** are studying microbial ecology, decomposition and the nitrogen cycle in desert grassland at the Sevilleta.

Nitrogen cycle. Nitrogen enrichment of the biosphere is an expanding problem to which arid ecosystems may be particularly sensitive. In semi-arid grasslands, scarce precipitation uncouples plant and microbial activities, and creates within the soil a spatial mosaic of rhizosphere and cyanobacterial crust communities. We are investigating the impact of elevated N deposition on these soil microbial communities at a grama-dominated long-term N fertilization experiment established in 1995. Since 1995 10 replicate 5x10m plots have received a total of 10g Nm-2 in two seasonal applications (spring, fall) of 5gNm-2. For this study, soil samples were collected in July 2004, following two years of severe drought, and again in March 2005 following a winter of record high precipitation. Soils were assayed for potential activities of 20 extracellular enzymes and N_2O production. The rhizosphere and crust-associated soils had peptidase and peroxidase potentials that were extreme in relation to those of temperate soils. N addition significantly enhanced glycosidase and phosphatase activities and depressed peptidase. In contrast to temperate forest soils, oxidative enzyme activity did not respond to N treatment. Across sampling dates, EEA responses correlated with inorganic N concentrations. N_2O generation did not vary significantly with soil cover or N treatment. Microbial responses to N deposition in this semi-arid grassland were distinct from those of forest ecosystems and appear to be modulated by inorganic N accumulation, which is linked to precipitation patterns. A manuscript describing this work is in review at Microbial Ecology.

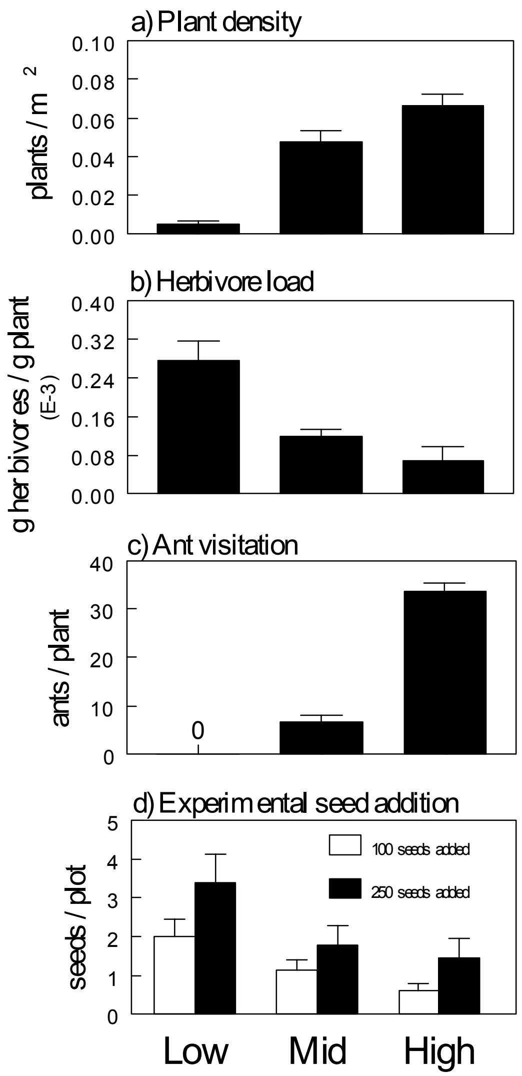
We are extending our analyses of N deposition effects on soil processes to include microbial community composition. Fungal 18S and ITS fragments have been amplified and cloned from grama roots, rhizosphere soil and crust soil using several primer sets. To date about 300 sequences have been collected. Database comparisons indicate a highly diverse fungal community. Dark septate endophytes (Pleosporales and others) and arbuscular mycorrhizal fungi (*Glomus*) dominate in the roots, while the soils contain a diverse mix of ascomycetes, chytrids and basidiomycetes. We have approximately 60 fungal isolates in culture, which we plan to screen for genes that code extracellular proteases and oxidases. Sequencing will continue until we can establish comparative rarefaction curves for each soil type and experimental treatment. A similar fungal community analysis is in progress for ecosystems established on gypsum soil, which represent an even more selective environment.

Radiative decomposition: Standard models for plant litter decomposition, based on measures of N or lignin content and modulated by temperature and moisture variables, do not accurately predict absolute or even relative decomposition rates in arid environments. Many researchers have proposed that photodegradation, rather than microbial degradation, dominates decomposition processes in arid environments, effectively uncoupling soil carbon and nitrogen cycles. However, there has been very little direct investigation. To study this phenomenon, a field experiment was established in May 2004. The 2 x 3 factorial design includes two blocks, one receiving water amendments to facilitate microbial activity and one receiving only ambient precipitation. Within each of these blocks, three replicate plots of each treatment were established: a control treatment receiving ambient levels of UV radiation, a shade treatment receiving 20% of ambient UV levels, and a high UV treatment with UV levels 25% higher than ambient levels. Litterbags containing senesced leaf litter of juniper (*Juniperus monosperma*), piñon (*Pinus edulis*), and cottonwood (*Populus deltoides*) were placed in each plot. Litterbags have been collected every two months for analysis of mass loss, extracellular enzyme activity, nutrient immobilization and dissolved organic matter (DOM) content.

After 385 days for juniper and piñon and 190 days for cottonwood, all litter species show the highest mass loss rates under elevated UV: rate constants are approximately two times larger than those measured for litter in the shade treatment. Light exposure has also significantly affected oxidative and hydrolytic enzyme activities. The EEA effects vary by litter type but suggest that UV exposure has a selective effect on microbial community composition. The composition of extractable DOM also varies with radiative treatment, as measured by both spectroscopic (UV absorbance and fluorescence profiles) and bacterial growth bioassays. Other analyses are still in progress. This study will continue thru 2005.

Producer dynamics

Fig 7. Variation along an elevational habitat gradient in: a) tree cholla density, b) herbivore load (herbivore mass/resource mass), c) ant (*Liometopum apiculatum*) visitation to tree cholla extra-floral nectarines, d) seedlilng recruitment in experimental see addition plots.



Tom Miller, a Ph.D. student with **Svata Louda** at the University of Nebraska-Lincoln is conducting his dissertation research at the Sevilleta. The central goal of his research is to understand how species interactions and abiotic context combine to generate patterns of distribution and abundance. As a model system, Tom is studying the interactions among tree cholla cacti (*Opuntia imbricata*), specialized cactus-feeding insect herbivores, nectar-feeding ants, and arthropod predators. These species occur across a grassland-mountain elevational habitat gradient at the Sevilleta National Wildlife Refuge, and their relative abundances vary systematically with elevation. Patterns of abundance (Fig 7a-c) suggest the hypotheses that: 1) habitat-specific mutualistic interactions between tree cholla and nectar-feeding ants (*Liometopum apiculatum*) at high elevation restrict insect herbivores to lower elevations; and 2) habitat-specific pressure from insect herbivores at low elevation limits tree cholla abundance there. Hypothesis 2 is further supported by experimental results indicating that abiotic constraints on seed germination or seedling survival cannot explain the observed pattern of plant abundance (Fig 7d). Combined, these hypotheses suggest a spatially-dynamic, trait-mediated trophic cascade that generates patterns of abundance across a landscape. This approach to testing these hypotheses consists of experimental manipulations of interaction strengths that are spatially explicit with respect to position along this gradient. This work is designed to tease apart correlations and causations, and match pattern with process.

Burt and **Rose Pendleton** (Senior Scientists, USFS Rocky Mountain Research Station, Albuquerque) along with **Karen Wetherill** (Head of the Sevilleta Field Crew) are studying the mechanisms by which creosotebush is expanding its range and dominance at the Sevilleta. One of the main questions pertaining to the expansion of *Larrea* into the grassland community centers on establishment of *Larrea* through seed. Unpublished data (T. Lowery, *pers. comm.*) indicated that Chihuahuan populations of *Larrea* do not expand clonally as has been reported for Mojave populations. Components of seedling establishment include pollination mode, seed production, dispersal, germination, and environmental conditions necessary for seedling establishment. This research addresses establishment and persistence of *Larrea* through a series of experiments. To date, we have 1) bagged isolated and core *Larrea* plants to determine degree of self-pollination, 2) compiled a list of pollinators found on isolated plants within the grassland as well as for the core population, 3) examined the flowering phenology of isolated and core shrubs, 4) established long-term low- medium- and high-density plots that will allow us to study *Larrea* demographics and track changes in density through time, 5) continued McKenzie Flat fire effect studies looking at shrub mortality and the effect of fire on seedling recruitment, and 6) begun studies of *Larrea* seed dormancy, seed banking, and seedling emergence using 2005-collected seed.

In addition, we have begun a new study looking at fire effects on floral resources for pollinators. In spring and fall of 2005 we have and will conduct insect sweeps, install and monitor bee traps, and make weekly counts of the numbers of flowers of each herbaceous forb species available during peak flowering periods. We have also established seedling emergence plots of 20 forb species looking at plant phenology, including emergence and flowering, and plan growth chamber studies to quantify nectar and pollen production of each species.

In 2005, **Deb Peters** (Sevilleta Senior Scientist) continued her research on ecotone and patch characterization at the Sevilleta. As part of her patch dynamics studies, she investigated the factors influencing invasion success and patch expansion of creosotebush (*Larrea tridentata [Zygophyllaceae]*) within a mosaic of communities dominated by either blue grama or black grama. Frequency of occurrence, height, and surface area of saplings (n=134) and patches of adult plants (n=247) of creosotebush were measured within a mosaic of communities dominated either by the Chihuahuan Desert species, black grama, or the shortgrass steppe species, blue grama located within 1 km of the creosotebush dominated community. Sapling age and year of establishment were estimated from height using previously developed relationships. Cover by species or functional group inside each shrub patch was estimated and compared with the vegetation in the surrounding grass patch. Distance between each creosotebush sapling or patch and the community dominated by this species, the major source of seeds, was measured to examine dispersal constraints.

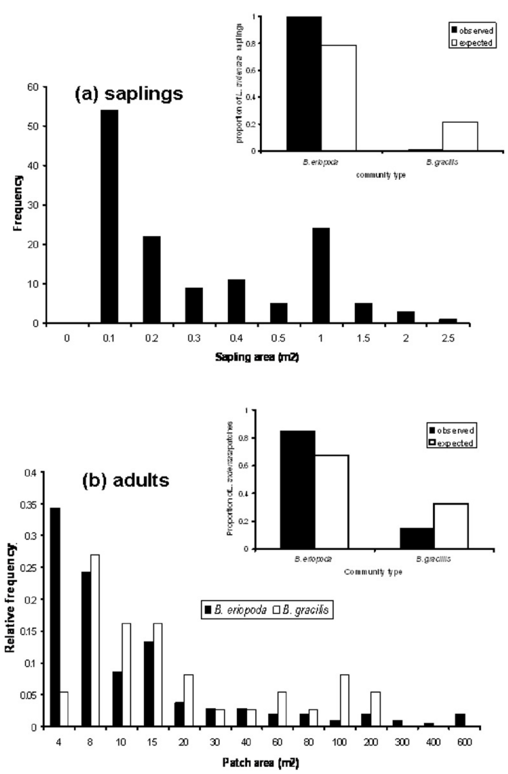


Fig. 8. (a) Frequency distribution of the area of creosotebush saplings found within black grama dominated communities. One sapling found in a blue grama community is not shown. Insert: observed and expected number of creosotebush saplings located within communities dominated by either blue grama (*B. gracilis)* or black grama (*B. eriopoda)*. (b) Frequency distribution of the area of creosotebush patches found within either blue grama or black grama dominated communities. Insert: observed and expected number of creosotebush patches located within communities dominated by either blue grama or black grama.

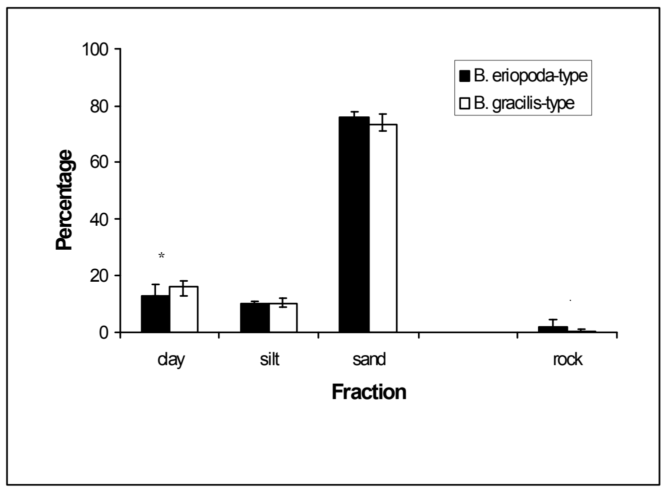


Fig 9. Preliminary analysis of particle size distribution in blue and black grama patches.

Results show that creosotebush saplings (1%) and adult patches (15%) rarely occur in blue grama dominated communities (Fig. 8)(Kröel-Dulay et al. 2004). Establishment events occurred yearly over the past 18 years with the number of saplings related to amount of monsoonal rainfall. Similar relationships between number of plants and patch area in both community types indicate similar rates of patch expansion. Cover of perennial forbs was higher and cover of dominant grasses was lower in creosotebush patches compared with the surrounding vegetation for both community types. There was no relationship between distance from the creosotebush dominated community and sapling age or patch area. Differential invasion success in two grassland communities at this biome transition zone was most likely related to the germination and establishment of colonizing shrub plants rather than seed dispersal constraints or differences in patch expansion of existing plants. The persistence of grasslands at this site despite region-wide expansion by creosotebush may be related to the presence and spatial distribution of blue grama-dominated communities that resist woody plant invasion.

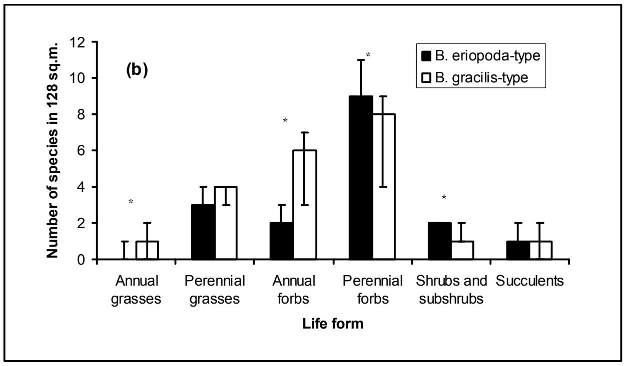


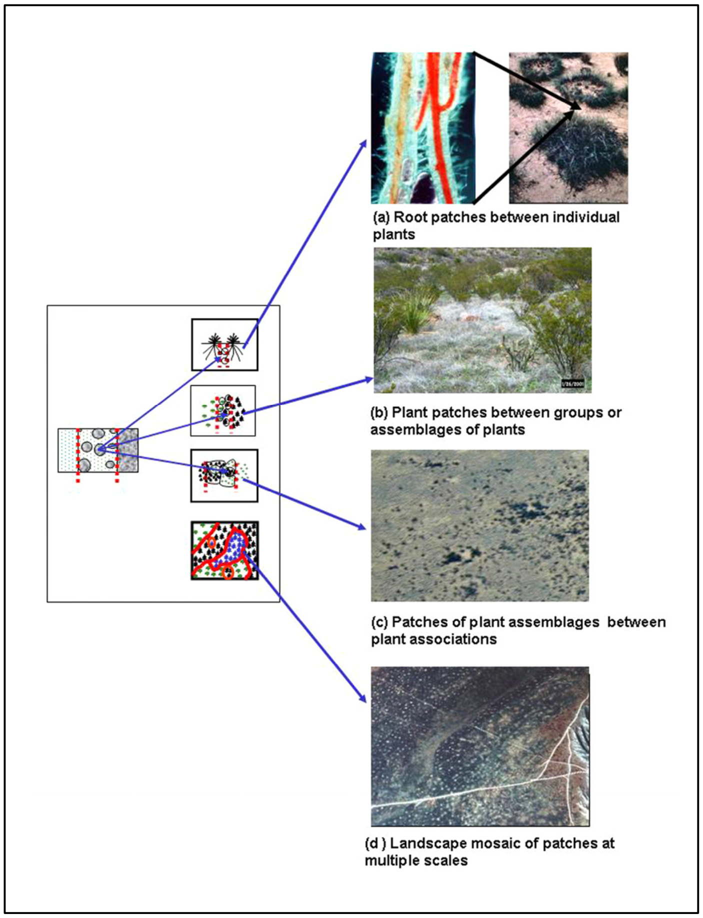
Fig 10. Species composition in blue and black grama patch types.

We continued to analyze the vegetation, soil, and DEM data collected from eight black grama-blue grama transitions, and four creosote-black grama transitions located throughout McKenzie Flats. The following data were collected every 5 m along transects that traversed each ecotone (n=1440): elevation (mm) using a Total Position Station, vegetation cover by species using 0.5 m^2 quadrats, and the GPS coordinates. For two of the four transects, soil samples were collected every 5-10 m from three depths (0-1, 1-5, and 5-20cm). These samples (n=2520) are being analyzed for particle size distribution. We are using the vegetation, soils, and elevation data to test the hypothesis that different kinds of transition zones are found across McKenzie Flats (stable, stationary, shifting), and that these transition zones are controlled by different environmental factors. In addition, a total of 800 blue grama and 400 black grama small patches (< $10m^2$) were measured and geo-referenced.

We also compared the plant species and life form composition of blue grama and black grama patch types at the Sevilleta (Peters et al. *submitted*). Patches were sampled at multiple scales for the occurrence of subordinate species. Association of species with patch type was tested with Chi^2. We also compared our results with the geographic range of each species using floristic manuals and distribution maps to determine if a broader association exists between species and biomes. We found that soils of *B. gracilis*-dominated patches had higher clay and lower rock contents compared with soils of *B. eriopoda*-dominated patches (Fig. 9).Of the 52 species analyzed, most were found associated with one patch type (54%). Sixteen species were associated with *B. gracilis*-dominated patches and 12 species with *B. eriopoda*-dominated patches (Fig. 10). Patches dominated by *B. gracilis* were richer in annuals whereas patches dominated by *B. eriopoda* contained more perennials. Both differences in species characteristics and soil texture between patch types contribute to patch-scale variation and changes in biodiversity across the landscape. Species associated with one of the two patch types occurred across broad geographic ranges. Our results show that patch types at this biome transition zone have characteristic life form and species composition, but the distribution of each subdominant species in these patches cannot be predicted based on its geographic range.

Ecotone conceptual framework. We described an operational framework for understanding and predicting dynamics of these biotic transitions for a range of environmental conditions across multiple spatial scales (Peters et al. *in press*). We define biotic transitions as the boundary and the neighboring states, a more general definition than typically denoted by the terms boundary, ecotone, edge or gradient. We use concepts of patch dynamics to understand the structural properties of biotic transitions and to predict changes in boundaries through time and across space. We developed testable hypotheses, and illustrated the utility of our approach with examples primarily from the Sevilleta (Fig. 11). We discuss three types of ecotones with different dynamics and key controlling factors (stable, shifting, directional). Our framework provides new insights and predictions as to how landscapes may respond to future changes in climate and other environmental drivers.

Fig 11. Conceptual framework of biotic transitions using examples from the Sevilleta and other sites in the Chihuahuan Desert.



Synthesis using simulation modeling. We continue to develop and use a suite of simulation models to address dynamics of arid and semiarid systems. We developed a cellular automata model to simulate landscape scale dynamics across different types of ecotones (stable, shifting, directional) between the three dominant species (blue grama, black grama, creosotebush) at the Sevilleta. The model represents vegetation dynamics under changes in climate and grazing regime through time. In collaboration with the Jornada LTER, we are continuing to modify the ECOTONE simulation model by incorporating the horizontal and vertical distribution of water, nutrients, and soil particles by wind and water across a range of spatial scales, from plants to patches and landscape units. We recently completed the recoding of our soil water model (SOILWAT) into C and C++ to allow easier multi-scale simulations. We are also working with Greg Okin at the University of Virginia to link ECOTONE with his model of wind redistribution of soil particles to allow effects of dynamic vegetation on wind erosion-deposition dynamics. We are also working with Tony Parsons and John Wainwright of England to link ECOTONE with their model of horizontal soil water redistribution across ecotones.

Long term studies of effects of disturbances. We are continuing to examine the effects of small, patchy disturbances on vegetation dynamics at ecotones. We monitor vegetation cover by species annually on 3m x 4m removal plots at five sites located along a grassland-shrubland ecotone on McKenzie Flats as well as a sixth site along the foothills of Los Pinos that represents a predominately blue grama community with very small amounts of black grama and no creosotebush. The five sites have been monitored since 1995 and the sixth was added in 1998. We also added a series of plots with total removals in 2003. Long-term monitoring is needed to determine the species that dominate following the loss of the current dominant.

Consumer dynamics

Ana Davidson (former graduate student, now a postdoc with Gerardo Ceballos at UNAM) and **David Lightfoot** (UNM staff scientist) looked at the keystone role of prairie dogs (*Cynomys* spp.) and banner-tailed kangaroo rats (*Dipodomys spectabilis*) in three grassland ecosystems. Their keystone status is attributed primarily to the effects of their burrowing and foraging behavior. However, these species co-occur in the arid grasslands of the southwestern United States and in Mexico, and differ ecologically in several important respects. We established a cross-site research project that evaluated the comparative and interactive effects of prairie dogs and banner-tailed kangaroo rats in areas where they co-occur at the Sevilleta National Wildlife Refuge, New Mexico, and at Janos, Chihuahua, Mexico (Davidson 2005, Davidson and Lightfoot in press, submitted). We focused our research on the impacts of these rodents on grassland plant and animal communities. We found that vegetation cover, structure, and species richness varied across a gradient extending out from the mound centers, and these patterns differed between prairie dog and kangaroo rat mounds. Certain species and functional groups of plants and arthropods associated differentially with mounds and landscape patches occupied by prairie dogs and banner-tailed kangaroo rats. Where both species co-occurred locally there was greater soil disturbance, more organic material from their feces, and higher activity of other animals, including antelope, rabbits, lizards, and other rodents. The overall effect of prairie dogs and kangaroo rats was to create a mosaic of different patches across the landscape such that their combined activities increased landscape heterogeneity and plant and animal species diversity (Fig. 12).

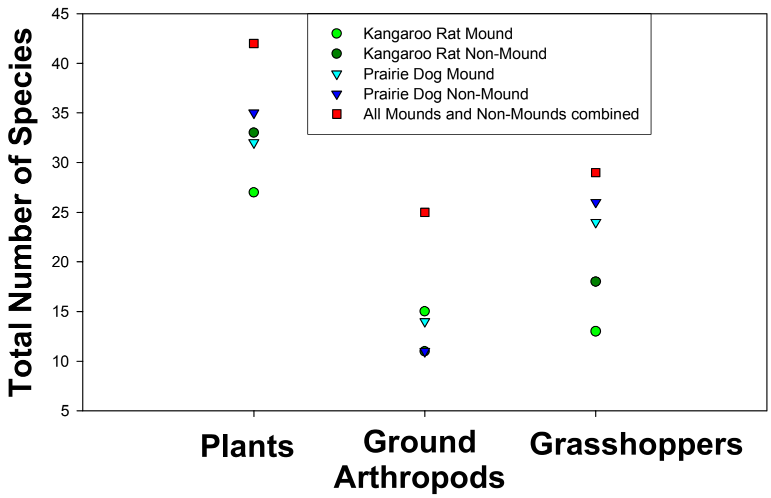


Fig 12. The total number of plants, grasshoppers and other ground-dwelling arthropods on and off K-rat and Prairie Dog mounds at the Sevilleta National Wildlife Refuge. Prairie dog mounds, kangaroo rat mounds, and non-mounds supported different assemblages of plant and arthropod species, and on a per unit area basis, the total accumulated number of species at the mound and landscape-scales was enhanced where prairie dogs and kangaroo rats co-occurred.

Selene Baez, **Scott Collins**, **David Lightfoot** and **Terri Koontz** (graduate student) analyzed data from our long-term small mammal exclosure study established in 1995. Water is widely acknowledged to be the key limiting resource in aridland ecosystems where the amount and timing of precipitation events strongly affect net primary productivity. On the other hand, numerous experimental studies have demonstrated strong consumer control on the composition, production and diversity of aridland plant communities. The mechanisms driving these changes involve consumption of green tissue, seed predation, shifts on species interactions, and alteration of responses to bottom-up inputs. These seemingly contradictory patterns result from non-linear dynamics between rainfall, net primary production and consumers in arid systems which impart high temporal variation in the strength of bottom-up and top-down controls on trophic interactions in aridland ecosystems. Reconciling these competing hypotheses regarding the primacy of top-down and bottom-up controls in aridland ecosystems requires long-term experimental manipulation of consumer and producer communities. To do so, we used a long-term small mammal exclusion experiment designed to evaluate the relative role of bottom-up and top-down controls on plant community structure in low productivity grass- and shrub-dominated Chihuahuan Desert plant communities Baez et al. *submitted*). Specifically, we assessed how bottom-up pulses cascade through vegetation to affect rodent populations and how rodent populations affect plant community structure and dynamics.

We used plant species composition data from 36 permanent 1m2 quadrats in each of four replicate rodent exclosures and open areas in grass- and shrub-dominated vegetation to assess the impacts of small mammals on vegetation dynamics. Rodent abundances outside the exclosures were quantified using data from our core LTER small mammal trapping webs.

We found no significant differences in the cover, species richness, and heterogeneity of grass or shrub vegetation between rodent access and rodent removal treatments (Fig 13). In shrub vegetation, however, plots without rodents had a significantly higher rate of directional change over time compared to sites with rodents (One-way ANOVA, P=0.005, R^2= 0.54, N=8). In grass vegetation, there were no differences in the rate of community change over time for plots with and without rodents (One-way ANOVA, P=0.52, R^2=0.06, N=8).

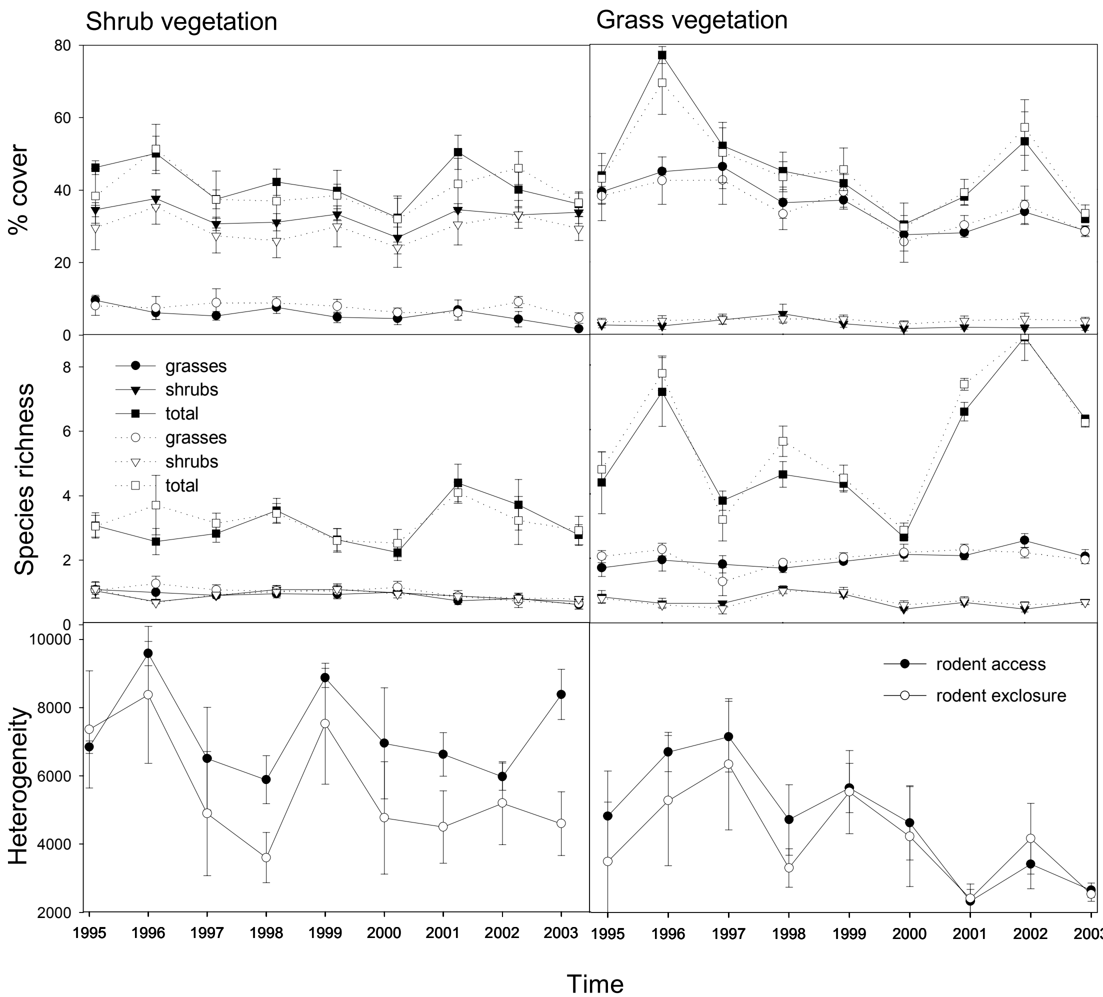


Fig 13. Cover and species richness of functional groups of grass- and shrub-dominated vegetation in rodent removal and control plots.

Overall, we found a positive relationship between precipitation and total cover, and to a lesser extent, diversity of plant functional groups. Cover and diversity in the grassland plots responded positively to summer rainfall, whereas shrub vegetation responded positively to winter rainfall. In only one case did rodent removal affect plant functional type response to seasonal precipitation. In shrub vegetation, control plots had significantly higher heterogeneity compared to rodent removal plots. There were no significant precipitation by treatment interactions.

Precipitation was positively related to consumer density. In grasslands, rodent densities increased in response to summer precipitation of the previous year. Oddly, densities of rodents in grass vegetation were negatively related to the previous year's winter precipitation. This probably resulted from a negative relationship between summer and winter precipitation over the study period rather than a direct reduction of rodent densities due to increased winter rainfall. In shrub vegetation, rodent densities were positively related to summer precipitation of the previous year, and to winter-spring precipitation in the current year.

It is hypothesized that the regulation of plant communities depends on the number of trophic levels of the system, on plant defense resources, and on the level of primary productivity that sustains variable densities of consumers that are interactively controllers or controlled by plants. Characterizing the interactions between producers, consumers, and precipitation is an important step toward understanding the temporal dynamics of bottom-up and top-down regulatory forces in ecosystems. In our arid Chihuahuan Desert system, rodents exerted no top-down control on plant community dynamics, species richness, composition and cover in desert grassland and exerted only minor control in shrub-dominated vegetation. We conclude that bottom-up forces strongly regulate vegetation structure and dynamics in this aridland ecosystem. We suspect that the lack of top-down control results from chronically low rates of net primary production which constrains densities of rodents and other consumers. Whether or not subtle but persistent effects of consumers will eventually lead to changes in community composition in this system remains to be seen.

Andrew Edelman (graduate student) is studying population dynamics and behavior of banner-tailed kangaroo rats (*Dipodomys spectabilis*) on the northern end of McKenzie Flats at the Sevilleta. This summer he began a monthly census and live trapping (3 days/month) of K-rat mounds. The study area is 17.8 ha and contains 147 mounds (8.3 mounds/ha). Over 5 months of trapping, 158 individuals have been marked (females: 37 adults, 42 subadults; males: 26 adults, 52 subadults). Occupancy rate of mounds, based on sign, has fluctuated from a low of 46.3% in March 2005 to a high of 81.7% in August 2005. The large increase in occupancy rate appears to be due to dispersal of subadult kangaroo rats from natal mounds. 12 new mounds have also been built during a 6-month period (8% increase in mounds). Of the 24 subadults where the mother is known, 16.7% have inherited the natal mound after their mother died or disappeared (n = 4), 16.7% have inherited the natal mound after the mother moved to a different mound (n = 4), 29.2% have dispersed to an unoccupied mound (n = 7), and 37.5% have disappeared or remained at the natal mound with the mother (n = 9). Based on live trapping, 75% of adult females (n = 28) and 62% of adult males (n = 16) survived 5 months.

Results from the study on prairie dogs and plague by graduate student **Megan Friggens** of Northern Arizona University show to date that no rodent or flea species collected on the Sevilleta NWR have tested positive for plague. Neither have any of the flea species known to be efficient vectors of plague been found on Sevilleta rodents (Table 1). However, two groups of rodents, *Peromyscus* spp. and *Dipodomys* spp., caught in high numbers on the Sevilleta NWR, are known to be resistant to plague related mortality and have been implicated as maintenance hosts of plague in other ecosystems. *Peromyscus* spp. are found in higher elevation sites on the Sevilleta, while the *Dipodomys* spp. are most concentrated at the site of the prairie dog town. The unique distribution of these rodent species may allow us to define the ultimate role of dispersal in introducing plague to prairie dog colonies. Flea burdens of most rodents appear to be greatest in the spring, which likely corresponds to flea microhabitat (both soil moisture and temperature) requirements (Table 1). No unusual flea-host associations (flea species on non-normal host species) have been found, indicating that a generalist flea species (that feeds on multiple host species) may be required for pathogen transmission between different host species. *Dipodomys spectabilis* carried the greatest diversity of flea species including some generalist species. The dense concentration of *Dipodomys* on prairie dog towns combined with their propensity to carry generalist species of fleas points to the potential role of *Dipodomys* spp. in transferring fleas and pathogens among sympatric rodent species. A closer analysis of the association of *Dipodomys* and *Cynomys* in desert grasslands in conjunction with analyses of the interspecific pathogen transmission between *Dipdomys* and other rodents, may reveal that *Dipodomys* spp. have a huge potential to mediate plague outbreaks in Gunnison's prairie dog populations.

Table 1. Species and prevalence of infestation of fleas collected from 8 rodent species from a prairie dog town on the Sevilleta NWR, New Mexico.

Host	FleaSpecies	Overall Prevalence	Prevalence
Cynomys gunnisoni		0.69	
	Oropsylla hirsuta		0.65
Dipodomys ordii		0.06	
	Meringis arachis		0.06
Dipodomys spectabilis		0.48	
	Echidnophaga gallinacea		0.04
	Malaraeus sinomus		0.04

	Meringis arachis		0.43
Perognathus flavus		0.01	
	Meringis shannoni		0.01
	Orchopeas leucopus		0.01
Peromyscus boylii		0.10	
	Malaraeus sinomus		0.10
Peromyscus eremicus		0.13	
	Orchopeas leucopus		0.13
Peromyscus maniculatus		0.10	
	Peromyscopsylla hesperomys		0.10
Peromyscus truei		0.07	
	Malaraeus sinomus		0.07

Table 2. Flea species collected from 8 rodent species captured during the spring or fall field seasons from a prairie dog town on the Sevilleta NWR, New Mexico.

Host	FleaSpecies	Spring	Fall
Cynomys gunnisoni			
	Oropsylla hirsuta	x	
Dipodomys ordii			
	Meringis arachis	x	
Dipodomys spectabilis			
	Echidnophaga gallinacea		x
	Malaraeus sinomus		x
	Meringis arachis	x	
Perognathus flavus			
	Meringis shannoni	x	
	Orchopeas leucopus		x
Peromyscus boylii			
	Malaraeus sinomus		
Peromyscus eremicus			
	Orchopeas leucopus	x	
Peromyscus maniculatus			
	Peromyscopsylla hesperomys	x	
Peromyscus truei			
	Malaraeus sinomus	x	

Baez, S., S.L. Collins, D. Lightfoot and T. Koontz. Effects of rodent removal on community dynamics in desert grassland and shrubland vegetation. Submitted to *Ecology*.

Cushing, J., K. Vanderbilt, J. Brunt, M. Jones, A. Gupta and P. McCartney. 2005. NSF Long Term Ecological Research Sites: *Praxis et Theoria* -- LTER Information Management and CS Research. Pages 303-307 in J. Frew, editor. Proceedings of the 17th International Conference on Scientific and Statistical Database Management, Donald Bren School of Environmental Science and Management, University of California, Santa Barbara, CA USA.

Davidson, A. D. 2005. The comparative and interactive effects of prairie dogs and banner-tailed kangaroo rats on plants and animals in the northern Chihuahuan Desert. Ph.D. Dissertation. The University of New Mexico.

Davidson, A. D. and D. L. Lightfoot. 2006. Interactive effects of two keystone rodent species in a desertified grassland, Chihuahua, Mexico. Accepted with revision by *Ecography*.

Davidson, A. D. and D. L. Lightfoot. The effects of prairie dogs and kangaroo rats on the structure of grassland arthropod communities. Submitted to *Oikos*.

Kröel-Dulay, Gy., P. Odor, D.P.C. Peters, and T. Hochstrasser. 2004. Distribution of plant species between patch types at a transition zone between two grassland biomes in North America. *Journal of Vegetation Science* 15: 531-538.

Palmer, M.A., E. Bernhardt, E. Chornesky, S.L. Collins, A. Dobson, C. Duke, B. Gold, R. Jacobson, S. Kingsland, R. Kranz, M. Mappin, F. Micheli, J. Morse, M. Pace, M. Pascual, S. Palumbi, J. Reichman, W.H. Schlesinger, A. Townsend, M. Turner, and M. Vasquez. 2005. Ecology for the 21st Century: An action Plan. Frontiers in Ecology and the Environment 3: 4-11.

Peters, D.P.C., J. Yao, and J.R. Gosz. Patch-scale invasion at a semiarid-arid transition zone: implications for landscape scale dynamics. Submitted to *Journal of Vegetation Science*.

Pennings, S.C., C.M. Clark, E.E. Cleland, S.L. Collins, L. Gough, K.L. Gross, D.G. Milchunas and K.N. Suding. 2005. Do individual plant species show predictable responses to nitrogen addition across multiple experiments? *Oikos* 110: 547-555.

Peters, D.P.C., J. R. Gosz, W.T. Pockman, E.E. Small, R.R. Parmenter, S. L. Collins, and E. Muldavin. Integrating patch and boundary dynamics to understand and predict biotic transitions at multiple scales. *Landscape Ecology*: in press.

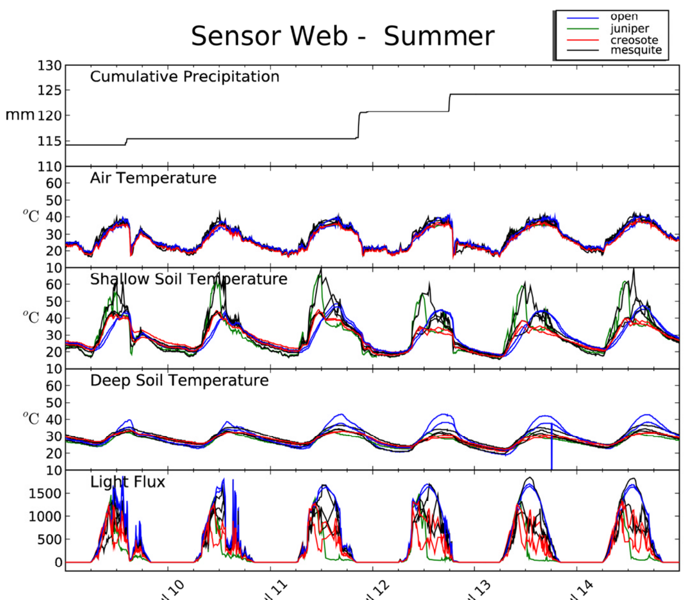
Suding, K.N., S.L. Collins, L. Gough, C. Clark, E.E. Cleland, K.L. Gross, D.G. Milchunas and S. Pennings. 2005. Functional- and abundance-based mechanisms explain diversity loss due to N fertilization. *Proceedings of the National Academy of Sciences* 102: 4387-4392.

FINDINGS

Climate and abiotic drivers

Fig. 1. Sensor Web 3.1 pod underneath a juniper tree.

Scott Collins (Sev PI), **Renee Brown** (Sevilleta Systems Administrator), **Doug Moore** (Met Central Czar) in collaboration with **Kevin Delin** and his team at the Jet Propulsion Lab (JPL), and **Luis Bettencourt**, **Aric Hagberg** and **Levi Larkin** of Los Alamos National Labs (LANL) are developing data analysis and QA/QC protocols for wireless Sensor Web enabled microclimate monitoring for ecological research (Palmer et al. 2005). Specifically, we are using Sensor Web 3.1 to address the question, are all resource islands equal? A fundamental concept in arid land research is the development of island of fertility under woody plants as desertification occurs. However, it is not clear that all such islands are ecologically equivalent. In fall 2003 we installed 12 Sensor Web pods in a study area near the Sevilleta Field Research Station to measure microclimate variables in three open areas, and under three individuals each of creosotebush, juniper, and mesquite (Fig 1). Sensor Web 3.1 pods record the following microclimatic variables every ten minutes: soil temperature (2 depths), soil moisture, air temperature, relative humidity and light. The collaborators from LANL are developing data extraction and QA/QC protocols for analyzing large streams of wireless sensor data. In particular, the group is developing QA/QC algorithms that can be embedded in the Sensor Web network to identify outlier data points on the fly.



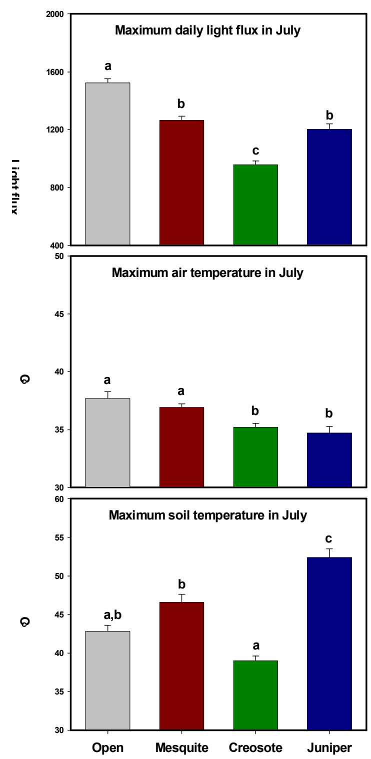


Fig 2. Example of data streams for a five day period in July 2004 (above). Statistical analysis of maximum daily light flux, maximum daily air temperature and maximum daily soil temperature for July 2004 in open areas and areas beneath three shrub species at the Sevilleta (right).

Results indicate that there are significant differences in microclimate under each species leading to greater resource heterogeneity in aridland ecosystems. An example data output stream from the Sensor Web is shown in Fig. 2). Differences in summer light flux beneath species are evident, both in maximum light

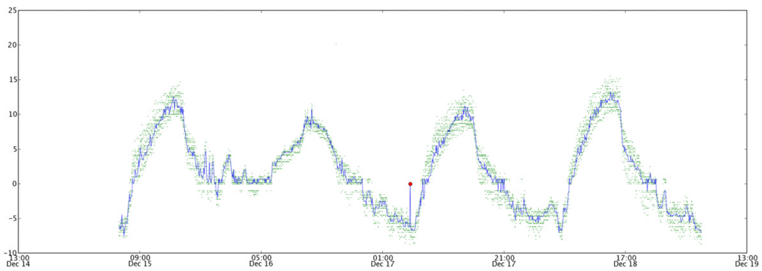


Fig 3. Example of QA/QC procedure. The blue trace is Air Temperature from Pod 12 and the Green Points are from a neighboring pod. The red point by itself is within the regular range of data points, but is out of range for the measurement period (>3 standard deviations away from neighbors [99% CL]. Error detection algorithms can be embedded into the Sensor Web network to detect and flag odd data values.

levels and time of day at which light levels peak. Also, fluxes in deep soil temperatures are generally greater in open areas compared to that under shrubs. Surprisingly, July maximum soil temperature was highest under the evergreen juniper (Fig 2). This occurs, most likely, because juniper litter and organic matter darken the soil such that a greater heat load is transferred to shallow soil depths in the summer time. QA/QC procedures are being developed based on the following premises: (1) environmental data are usually non-stationary because of diurnal, seasonal and annual cycles, (2) over short time frames data should be spatially and temporally coherent over neighboring sensors, (3) differences of commensurate measurements have statistics with bounded variances based on the central limit theorem, (4) because all Sensor Web pods share all data after every measurement, simple estimation methods (e.g. frequency estimation) can be used to characterize the mean and variance, (5) quality control can be implemented on the fly by excluding data points that have large differences to several neighbors, at some predetermined mean and variance (Fig 3). Once developed Sensor Web technology and embedded algorithms can be used to assess treatment efficacy within ecological experiments and eventually, actuation of experimental apparatus. Through our collaboration with JPL and LANL we are developing these algorithms in the context of newly NSF-funded project on the effects of nighttime warming, increased rainfall, and nitrogen deposition experiment at the Sevilleta. This work was presented by Collins et al. in an organized oral session on sensor networks for environmental research at the 2005 ESA Meeting in Montreal.

Water fluxes

Cliff Dahm (Sevilleta CoPI) and colleagues have been measuring rates of evapotranspiration (ET) in the riparian zone along the Rio Grande since 2000. Sites include a cottonwood dominated site with considerable amounts of non-native species in the understory that no longer floods (Albuquerque – SHK), a cottonwood dominated site that floods occasionally (Belen – BLN), a salt cedar and salt grass dominated site on the Sevilleta National Wildlife Refuge (Sevilleta NWR – SEV), a salt cedar dominated site at Bosque del Apache National Wildlife Refuge (Bosque del Apache NWR – BDAS), and a Russian olive and willow dominated site at La Joya State Game Refuge (La Joya SGR – LARO). Growing season ET at the SHK, SEV, and BDAS sites has been measured from 2000 – 2004, the BLN site was operational from 2000 – 2003, and the LARO site has made measurements from 2003 – 2004. Average annual growing season ET is highest in the SHK site with the mixed community of cottonwood overstory and a largely non-native understory. Average annual ET from the SHK site for 2000 – 2003 was 128 cm (± 4 cm). A partial restoration project involving the non-native understory species was begun in 2004. Annual ET in 2004 was 115 cm. The restoration project was completed in the winter of 2005, and annual ET estimates for the growing season of 2005 should help define the impact of this restoration project on overall riparian water use. Average annual ET from the BLN, BDAS, and LARO sites has been similar through the period of measurement (Fig 4). Average annual values for BLN, BDAS, and LARO have been 108, 106, and 112 cm, respectively. Standard error around the mean of these averages is greater at these sites compared to SHK. This reflects the greater interannual variability at these sites. For example, the average annual ET flux at the salt cedar dominated BDAS site has ranged from 88 to 119 cm. The lower values in 2002 and 2003 occur in years with complete drying of the Rio Grande and large draw downs in the water table during the growing season. Salt cedar, a facultative phreatophyte, adapts to the lowered water table by reducing transpiration and decreasing leaf biomass. The BDAS site is scheduled for a salt cedar eradication project in 2006, and this project will allow direct measurement of ET reduction from removal from a dense monotypic stand of

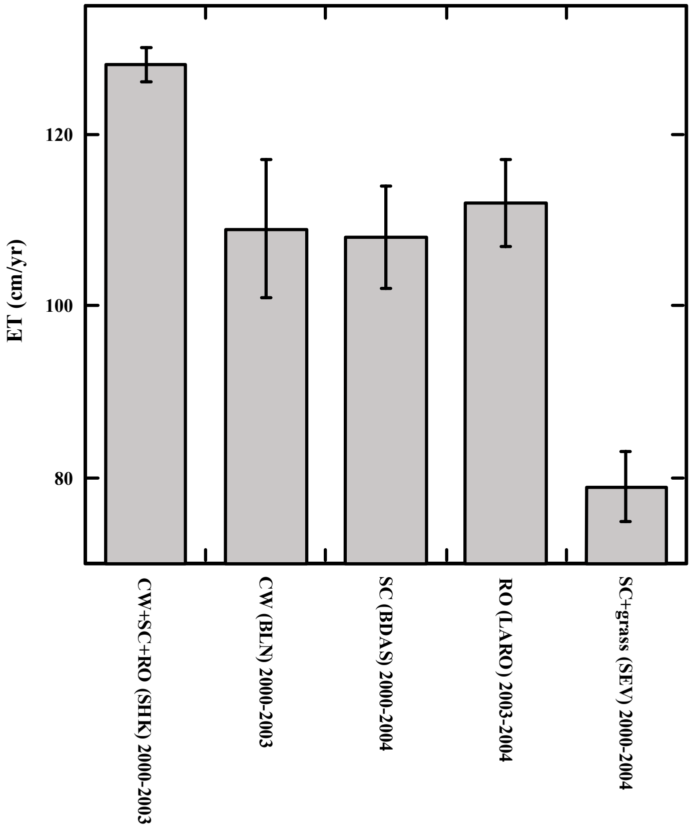


Fig 4. Annual ET (cm/yr) at five tower sites with differing types of riparian vegetation measured with three-dimensional eddy covariance instrumentation. The sites are in the riparian forest (bosque) along the Rio Grande in and adjacent to the Sevilleta NWR.

non-native vegetation. The SEV site has the lowest average rates of annual ET with an average for 2000 – 2004 of 79 cm (± 7). This non-flooding salt cedar and salt grass site is less densely vegetated with a relatively stable groundwater table due to a downstream irrigation diversion dam. Long-term deployment of eddy covariance equipment throughout multiple growing seasons has facilitated an excellent data base from which to evaluate water use by different types of riparian vegetation under differing hydrological conditions.

Biogeochemistry and soils

Debra Bryan (graduate student), **Carolyn Dumrose** (graduate student), **Grant Meyer** (LTER Senior Scientist) and **Les McFadden** (LTER Senior Scientist) all in the department of Earth and Planetary Sciences at UNM are studying deep soil structure and development on McKenzie Flats at the Sevilleta. During the spring and summer of 2005 soils and geologic media were exposed in four large (~11 m x 8m x >2 m depth) soil trenches constructed to OSHA safety requirements on McKenzie Flats. Two trenches were located approximately 3 km apart on an active alluvial fan of the granitic portion of the Los Piños Mountains. The northern-most fan trench study site is covered by C3 and C4 grasses (40%, *Bouteloua* and *Hilaria*), bare patches (29%), sand sage (22%), mormon tea (4%), soapweed yucca (1%) and cacti (1%). The southern-most alluvial fan site is dominated by C3 and C4 grasses (>60%), and also contains mormon tea, fourwing saltbush, soapweed yucca, and cacti. The southern-most trench has higher cover and few bare patches. Soils on both sites are polygenetic and are characterized by multiple depositional and erosional events followed by periods of quiescence leading to soil development. The lower-most exposed horizons are eroded, buried loamy soils exhibiting Stage III-IV calcic soil development indicating great age (several tens to hundreds of thousands of years). These buried soil horizons are overlain by multiple sandy fan deposits with clasts ranging from a few millimeters to several tens of centimeters in diameter. Some fan deposits exhibit incipient soil development but most are unaltered alluvium derived from the processes of erosion and deposition associated with fan development during wetter climatic periods. The lack of significant soil development indicates that these deposits are quite young (few thousands of years) and/or that they have been too disturbed to form soil horizons. Overlying these more clast-rich deposits are modern soils derived from sheet wash (coarse sand, pebbles, and few small cobbles) and eolian fine sand and silt. The modern soils exhibit “A” horizons (darkened by organic matter) and weak “B” horizons (some evidence for elluviation and formation of soil structure), and are likely a few hundred to a few thousand years old. The context of fine grained soils derived from sheet wash overlying cobble to boulder-rich fan sediments, is affecting water infiltration in the upper 0 – 30 cm of the subsurface. In the southern-most trench, some infiltrating waters have evaporated (depositing soil carbonate) prior to moving around boulders contained within the upper 13 cm. In the northern-most trench, the same observations were made for the upper 25 cm. The context of more permeable sediments overlying less permeable soils and sediments at depth may also be affecting soil hydrology: coarse and fine mormon tea and sand sage roots were observed exiting the face of the trench and traveling laterally for some distance before moving downwards. These observations were most often made at horizon boundaries with permeability contrasts in which the overlying sediments were more permeable than the underlying sediments. Water at these boundaries may temporarily "pond" as the process of infiltration begins to slow due to the decrease in permeability. Mormon tea and sand sage roots were found at 90 – 140 cm below the surface in the northern-most trench and mormon tea roots were found at 173 cm depth in the southern-most trench. The depth of root penetration also appears to be correlated to permeability as determined by clast size, clast sorting and the grain size of the matrix.

The remaining two trenches were located on a topographic high bounding the south-western extension of McKenzie Flats. This topographic high is probably a remnant fan surface formed by the Paleo-Palo Duro Wash approximately 800 – 900 Ka. The western-most trench is located near the Five Points Road intersection and is dominated by creosotebush (>75%) and barren patches of land. Some grama grasses are also present, but in small amounts. The lower-portion of the western-most trench contains several fluvial and sheet wash deposits (approximately 80 cm thick) that are nearly completely plugged with gypsic cements. The clasts contained within the lower-portion of the trench include gypsiferous limestones from the Yeso Formation, and are likely the source of the gypsic cements in the surrounding sediments. Immediately above these deposits is a thick (~90 cm), fine-grained, Stage IV+, petrocalcic soil horizon with large (filled) animal burrows and many pisolites. The presence of a laminar, brecciated and massively cemented petrocalcic horizon again indicates great age. The pisolites within this horizon are pebble-sized and contain multiple inner coatings of tan colored cements and one thin outer coating of soil carbonate. Above the surface of the petrocalcic soil is an erosional surface overlain by the modern soil. A thin (13 cm) horizon of unaltered fluvial sand, ripped up carbonate chunks, and eolian silt separates the modern soil from the underlying petrocalcic horizon. The modern soil is 18 cm thick and is derived from ripped-up soil carbonate chunks from the underlying petrocalcic horizon, fine grained sheet wash, and eolian silt. Coarse and abundant creosotebush roots were observed in every horizon, or pocket of sediment, not completely plugged by gypsic cements. This observation indicates that the gypsic cements are chemical or physical barriers to creosotebush roots, or both. Grass roots were observed in the modern soil only. A lens-shaped charcoal deposit was found in contact with the petrocalcic horizon and below the modern soil. This deposit has been sampled for radiocarbon dating.

The eastern Five Points trench is located on a broad, shallow drainage incising the old Paleo-Palo Duro fan deposit and is approximately 0.9 km to the southwest of the other Five Points trench. The most striking feature of this trench is that, despite the fact that it is over 2 m in depth, it is nearly uniformly composed of fine sand and eolian silt. Also, in contrast to all other trench sites, nearly all of the soil horizons are reddened and exhibit clay films (evidence for translocated clay and argillic soils). Like the western Five Points trench, the lower portions (lower four horizons) contain gypsum cements. However, very few Yeso Formation clasts (or any other clasts) were observed in the trench, so the source of the gypsum cements was not immediately determined. The vegetation cover at this trench site is mixed and typically co-dominated by grama grass, creosotebush and bare patches. The cover immediately above the trench was slightly more dominated by grama grass. Creosotebush roots exposed in the trench were not observed below the first clay-rich calcic horizon (~31 – 58 cm). Grass roots were thick in the upper horizons and helped to hold the vertical trench faces. To increase spatial representation of soils, additional trenches and soil cores will be examined in late 2005 and 2006.

Selene Baez (graduate student), **Joe Fargione** (postdoc), **Doug Moore** and **Scott Collins** analyzed our long-term atmospheric N deposition data. In southwestern North America, N deposition has increased steeply in the last two decades due to the rapid growth of urban areas, and to an increase in agriculture and animal production. Recent evaluations of the rates and patterns of N deposition show that areas located near large urban centers are more prone to receive high amounts of atmospheric N. However, for most major cities in the southwest, the actual magnitude and temporal trends in these effects are unknown. The limited available evidence suggests that N deposition in arid ecosystems could stimulate plant growth, but that such responses are often strongly limited by water availability. However, most such studies to date have been short-term N fertilization experiments that often use N addition rates significantly higher than current rates of atmospheric N deposition. Our study examined long- term data on N deposition and net primary productivity on desert grassland vegetation in the northern Chihuahuan Desert. We quantified the rates of N

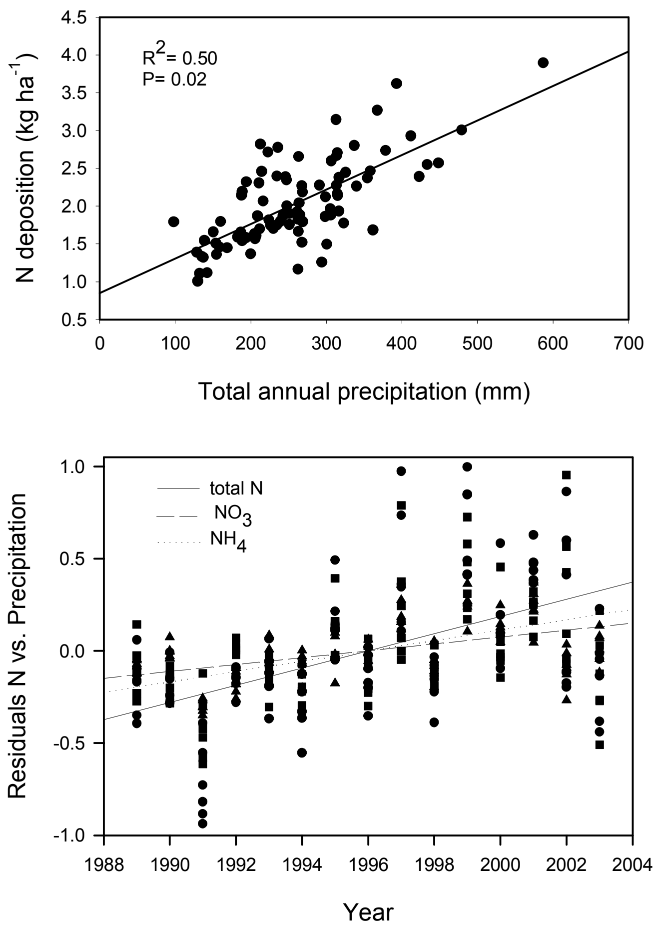


Fig 5. Linear regression of annual N deposition against precipitation (a). Linear regression of the residuals of total N, NO3 and NH4 versus annual precipitation (b). In both analyses each regression line was calculated with N=90.

deposition in native Chihuahuan Desert grass- and shrub-dominated plant communities and assessed the potential effects of N deposition on plant production and community composition in an ungrazed desert grassland community.

Nitrogen deposition was measured between 1989 and 2003 in a network of 6 funnel precipitation collectors located throughout the Sevilleta. These funnels collect all N deposited in precipitation (wet deposition) and any dry deposition that lands on or is washed into the sample. NO_3 and NH_4 were measured using a Technicon Auto-analyzer II and Dionex D-100 Ion Chromatograph that have comparable precision.

The amounts of total N deposited were positively related to precipitation volume (Fig 5). Total N, NO_3, and NH_4 deposition significantly increased from 1989 to 2003 (Fig 5). Total N deposition increased at a rate of 0.047 kg N ha^{-1} yr^{-1}, which corresponds to an annual increase of 2.3% of the long-term average annual deposition of 2.04 kg N ha^{-1}. Therefore, over 15 years of study, the Sevilleta has received 5.6 kg ha-1 of additional N that would not have been deposited if rates had not increased.

Deposition of NH_4 and NO_3 was positively correlated ($R^2 = 0.73$, $P < 0.0001$, $N = 90$). Over the years of the study more N was deposited as NH_4 (55.9%) than as NO_3 (44.1%), and the rates of deposition increase were non-significantly higher for NH_4 (0.028 kg ha^{-1} yr^{-1}) than for NO_3 (0.018 kg ha^{-1} yr^{-1}, P = 0.19 for *t* test of the slopes). The seasonal deposition rates of total N, NO_3 and NH_4 were higher during the summer than during the rest of the year. On average, 46% (0.93 kg ha^{-1}) of the annual N deposition occurred during the summer months. Furthermore, the proportion of N deposited annually during the summer months was positively related to total annual precipitation (Linear regression, R^2=0.12, P=0.001, N=90).

We are still analyzing the long-term relationships between N deposition and net primary production. Nevertheless, N deposition has increased in the Chihuahuan desert in central New Mexico from 1989 to 2003. The observed rate of N deposition, although low in comparison with regional estimates, is increasing. In this ecosystem N deposition maintains constant seasonal patterns related to precipitation. The increased rate of N deposition may not effect ANPP dramatically, but an on-going N fertilization experiment at our site suggests that chronic N deposition will eventually result in higher net primary production and potentially a decrease in legume abundance, a key plant functional type, as has been found across a number of sites in North America (Suding, Collins et al. 2005).

Bryan Brandel, a graduate student with **Carol Wessman** at the University of Colorado, is conducting his dissertation research (Scaling Ecosystem Processes in a *Larrea tridentata* Ecotone: The Influence of Landscape Structure on Ecosystem Function) at the Sevilleta. Woody plant encroachment has occurred in arid and semiarid grasslands worldwide, including the grasslands of the southwestern United States. At the Sevilleta National Wildlife Refuge (NWR) located in central New Mexico, creosotebush (*Larrea tridentata*) has replaced black grama (*Bouteloua eriopoda*) dominated semiarid grasslands along the Chihuahuan Desert biome transition zone. The mechanisms and consequences of woody plant encroachment are uncertain and complex and they have important implications for the functioning of semiarid ecosystems. The general goals of Bryan's research are to assess carbon and nitrogen storage and fluxes in relation to woody plant expansion in semiarid grassland and to utilize remote sensing to scale ecosystem transition processes to the landscape level. In 2003, four 50 m by 50 m plots in a line perpendicular to the shrub-grass transition boundary were established in each of three landscapes at the Sevilleta NWR near Five Points. Shrubland and grassland plots were established in the pure vegetation types while the middle two plots were located in the transition area and defined by relative shrub and grass covers. At random points within each plot, samples were collected beneath the nearest shrub patch, the nearest clump of grass, and the adjacent bare soil interspace. Soil organic carbon and total soil nitrogen to 20 cm depth were measured in the summer of 2003. *In situ* net nitrogen mineralization rates to 10 cm depth were measured for four periods during May to October 2004 and monthly during the 2005 growing season.

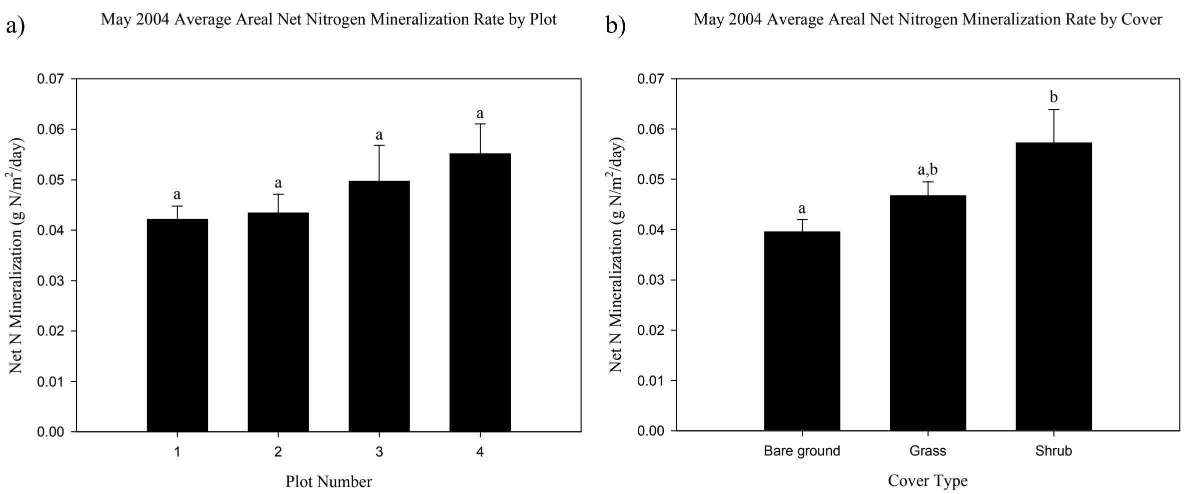


Fig 6. Average (+/- s.e.) net nitrogen mineralization rates by plot (a) and cover type (b) for May 2004 (n=153). Letters above the bars indicate significant differences at P<0.05l. (a) There were no significant differences in net nitrogen mineralization between plots (plot 1 is pure shrubland, plots 2 and 3 are located in the transition area, and plot 4 is pure grassland). (b) Average net N mineralization under shrub canopies was significantly greater than average net mineralization in bare ground areas.

In situ net nitrogen mineralization rates measured in May 2004 show significant differences for cover type, but not plot (Fig 6). Although there appears to be an increase in average net nitrogen mineralization across the transition from pure shrubland to pure grassland, these differences were not significant (Fig 6a). Average net nitrogen mineralization under shrubs (0.057 g N/m^2/day) was significantly greater than the average rate in bare ground (0.040 g N/m^2/day), while the average rate in grass (0.047 g N/m^2/day) was intermediate (Fig 6b). These preliminary results for *in situ* net nitrogen mineralization suggest fractional cover is the only information necessary for scaling nitrogen mineralization across the transition area to the landscape level. However, preliminary results for soil organic carbon and total soil nitrogen show significant differences due to plot and cover type. Thus, scaling these ecosystem properties to the landscape level requires considering both cover type and landscape position. Remote sensing analysis of aerial photography and NASA's Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) data will be used to determine fractional cover of shrubs, grass, and bare ground across the transition area. Fractional cover will then be used to scale field measurements including *in situ* net nitrogen mineralization rates, total soil nitrogen, soil organic carbon, and aboveground biomass carbon to the landscape level.

Bob Sinsabaugh (LTER Senior Scientist), along with graduate students **Chris Lauber, Marcy Gallo, Martina Stursova**, and **Andrea Porras-Alfaro**, and undergraduate students **Kylea Odenbach, Kendra Pitts**, and **Armida Carbajal** are studying microbial ecology, decomposition and the nitrogen cycle in desert grassland at the Sevilleta.

Nitrogen cycle. Nitrogen enrichment of the biosphere is an expanding problem to which arid ecosystems may be particularly sensitive. In semi-arid grasslands, scarce precipitation uncouples plant and microbial activities, and creates within the soil a spatial mosaic of rhizosphere and cyanobacterial crust communities. We are investigating the impact of elevated N deposition on these soil microbial communities at a grama-dominated long-term N fertilization experiment established in 1995. Since 1995 10 replicate 5x10m plots have received a total of 10g Nm-2 in two seasonal applications (spring, fall) of 5gNm-2. For this study, soil samples were collected in July 2004, following two years of severe drought, and again in March 2005 following a winter of record high precipitation. Soils were assayed for potential activities of 20 extracellular enzymes and N_2O production. The rhizosphere and crust-associated soils had peptidase and peroxidase potentials that were extreme in relation to those of temperate soils. N addition significantly enhanced glycosidase and phosphatase activities and depressed peptidase. In contrast to temperate forest soils, oxidative enzyme activity did not respond to N treatment. Across sampling dates, EEA responses correlated with inorganic N concentrations. N_2O generation did not vary significantly with soil cover or N treatment. Microbial responses to N deposition in this semi-arid grassland were distinct from those of forest ecosystems and appear to be modulated by inorganic N accumulation, which is linked to precipitation patterns. A manuscript describing this work is in review at Microbial Ecology.

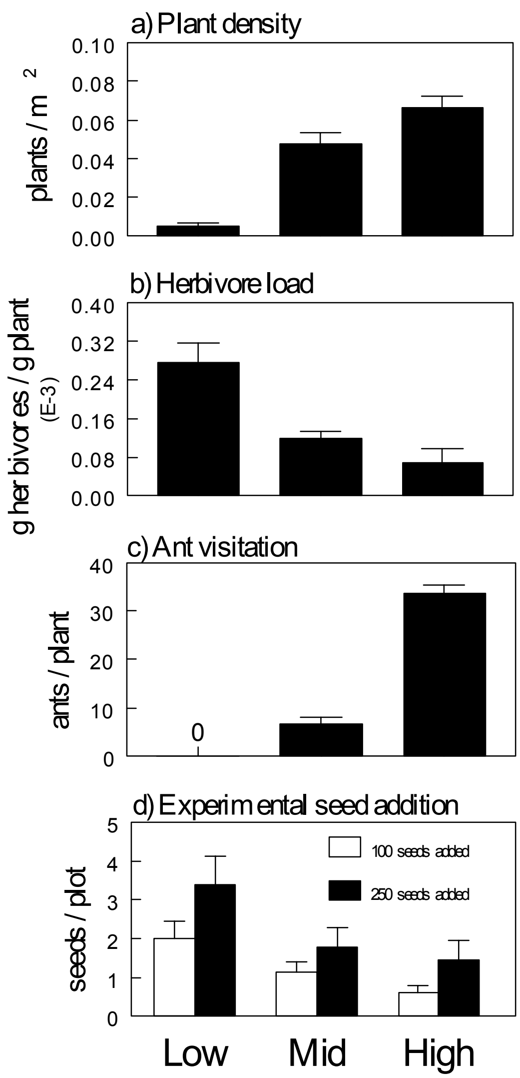
We are extending our analyses of N deposition effects on soil processes to include microbial community composition. Fungal 18S and ITS fragments have been amplified and cloned from grama roots, rhizosphere soil and crust soil using several primer sets. To date about 300 sequences have been collected. Database comparisons indicate a highly diverse fungal community. Dark septate endophytes (Pleosporales and others) and arbuscular mycorrhizal fungi (*Glomus*) dominate in the roots, while the soils contain a diverse mix of ascomycetes, chytrids and basidiomycetes. We have approximately 60 fungal isolates in culture, which we plan to screen for genes that code extracellular proteases and oxidases. Sequencing will continue until we can establish comparative rarefaction curves for each soil type and experimental treatment. A similar fungal community analysis is in progress for ecosystems established on gypsum soil, which represent an even more selective environment.

Radiative decomposition: Standard models for plant litter decomposition, based on measures of N or lignin content and modulated by temperature and moisture variables, do not accurately predict absolute or even relative decomposition rates in arid environments. Many researchers have proposed that photodegradation, rather than microbial degradation, dominates decomposition processes in arid environments, effectively uncoupling soil carbon and nitrogen cycles. However, there has been very little direct investigation. To study this phenomenon, a field experiment was established in May 2004. The 2 x 3 factorial design includes two blocks, one receiving water amendments to facilitate microbial activity and one receiving only ambient precipitation. Within each of these blocks, three replicate plots of each treatment were established: a control treatment receiving ambient levels of UV radiation, a shade treatment receiving 20% of ambient UV levels, and a high UV treatment with UV levels 25% higher than ambient levels. Litterbags containing senesced leaf litter of juniper (*Juniperus monosperma*), piñon (*Pinus edulis*), and cottonwood (*Populus deltoides*) were placed in each plot. Litterbags have been collected every two months for analysis of mass loss, extracellular enzyme activity, nutrient immobilization and dissolved organic matter (DOM) content.

After 385 days for juniper and piñon and 190 days for cottonwood, all litter species show the highest mass loss rates under elevated UV: rate constants are approximately two times larger than those measured for litter in the shade treatment. Light exposure has also significantly affected oxidative and hydrolytic enzyme activities. The EEA effects vary by litter type but suggest that UV exposure has a selective effect on microbial community composition. The composition of extractable DOM also varies with radiative treatment, as measured by both spectroscopic (UV absorbance and fluorescence profiles) and bacterial growth bioassays. Other analyses are still in progress. This study will continue thru 2005.

Producer dynamics

Fig 7. Variation along an elevational habitat gradient in: a) tree cholla density, b) herbivore load (herbivore mass/resource mass), c) ant (*Liometopum apiculatum*) visitation to tree cholla extra-floral nectarines, d) seedlilng recruitment in experimental see addition plots.



Tom Miller, a Ph.D. student with **Svata Louda** at the University of Nebraska-Lincoln is conducting his dissertation research at the Sevilleta. The central goal of his research is to understand how species interactions and abiotic context combine to generate patterns of distribution and abundance. As a model system, Tom is studying the interactions among tree cholla cacti (*Opuntia imbricata*), specialized cactus-feeding insect herbivores, nectar-feeding ants, and arthropod predators. These species occur across a grassland-mountain elevational habitat gradient at the Sevilleta National Wildlife Refuge, and their relative abundances vary systematically with elevation. Patterns of abundance (Fig 7a-c) suggest the hypotheses that: 1) habitat-specific mutualistic interactions between tree cholla and nectar-feeding ants (*Liometopum apiculatum*) at high elevation restrict insect herbivores to lower elevations; and 2) habitat-specific pressure from insect herbivores at low elevation limits tree cholla abundance there. Hypothesis 2 is further supported by experimental results indicating that abiotic constraints on seed germination or seedling survival cannot explain the observed pattern of plant abundance (Fig 7d). Combined, these hypotheses suggest a spatially-dynamic, trait-mediated trophic cascade that generates patterns of abundance across a landscape. This approach to testing these hypotheses consists of experimental manipulations of interaction strengths that are spatially explicit with respect to position along this gradient. This work is designed to tease apart correlations and causations, and match pattern with process.

Burt and **Rose Pendleton** (Senior Scientists, USFS Rocky Mountain Research Station, Albuquerque) along with **Karen Wetherill** (Head of the Sevilleta Field Crew) are studying the mechanisms by which creosotebush is expanding its range and dominance at the Sevilleta. One of the main questions pertaining to the expansion of *Larrea* into the grassland community centers on establishment of *Larrea* through seed. Unpublished data (T. Lowery, *pers. comm.*) indicated that Chihuahuan populations of *Larrea* do not expand clonally as has been reported for Mojave populations. Components of seedling establishment include pollination mode, seed production, dispersal, germination, and environmental conditions necessary for seedling establishment. This research addresses establishment and persistence of *Larrea* through a series of experiments. To date, we have 1) bagged isolated and core *Larrea* plants to determine degree of self-pollination, 2) compiled a list of pollinators found on isolated plants within the grassland as well as for the core population, 3) examined the flowering phenology of isolated and core shrubs, 4) established long-term low- medium- and high-density plots that will allow us to study *Larrea* demographics and track changes in density through time, 5) continued McKenzie Flat fire effect studies looking at shrub mortality and the effect of fire on seedling recruitment, and 6) begun studies of *Larrea* seed dormancy, seed banking, and seedling emergence using 2005-collected seed.

In addition, we have begun a new study looking at fire effects on floral resources for pollinators. In spring and fall of 2005 we have and will conduct insect sweeps, install and monitor bee traps, and make weekly counts of the numbers of flowers of each herbaceous forb species available during peak flowering periods. We have also established seedling emergence plots of 20 forb species looking at plant phenology, including emergence and flowering, and plan growth chamber studies to quantify nectar and pollen production of each species.

In 2005, **Deb Peters** (Sevilleta Senior Scientist) continued her research on ecotone and patch characterization at the Sevilleta. As part of her patch dynamics studies, she investigated the factors influencing invasion success and patch expansion of creosotebush (*Larrea tridentata [Zygophyllaceae]*) within a mosaic of communities dominated by either blue grama or black grama. Frequency of occurrence, height, and surface area of saplings (n=134) and patches of adult plants (n=247) of creosotebush were measured within a mosaic of communities dominated either by the Chihuahuan Desert species, black grama, or the shortgrass steppe species, blue grama located within 1 km of the creosotebush dominated community. Sapling age and year of establishment were estimated from height using previously developed relationships. Cover by species or functional group inside each shrub patch was estimated and compared with the vegetation in the surrounding grass patch. Distance between each creosotebush sapling or patch and the community dominated by this species, the major source of seeds, was measured to examine dispersal constraints.

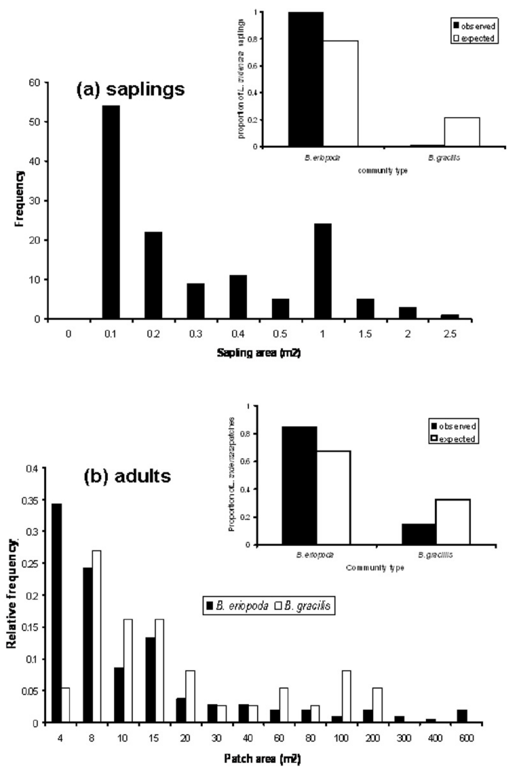


Fig. 8. (a) Frequency distribution of the area of creosotebush saplings found within black grama dominated communities. One sapling found in a blue grama community is not shown. Insert: observed and expected number of creosotebush saplings located within communities dominated by either blue grama (*B. gracilis)* or black grama (*B. eriopoda)*. (b) Frequency distribution of the area of creosotebush patches found within either blue grama or black grama dominated communities. Insert: observed and expected number of creosotebush patches located within communities dominated by either blue grama or black grama.

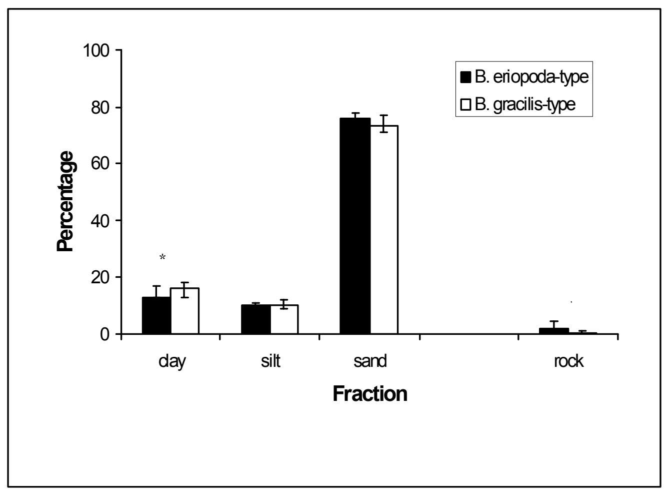


Fig 9. Preliminary analysis of particle size distribution in blue and black grama patches.

Results show that creosotebush saplings (1%) and adult patches (15%) rarely occur in blue grama dominated communities (Fig. 8)(Kröel-Dulay et al. 2004). Establishment events occurred yearly over the past 18 years with the number of saplings related to amount of monsoonal rainfall. Similar relationships between number of plants and patch area in both community types indicate similar rates of patch expansion. Cover of perennial forbs was higher and cover of dominant grasses was lower in creosotebush patches compared with the surrounding vegetation for both community types. There was no relationship between distance from the creosotebush dominated community and sapling age or patch area. Differential invasion success in two grassland communities at this biome transition zone was most likely related to the germination and establishment of colonizing shrub plants rather than seed dispersal constraints or differences in patch expansion of existing plants. The persistence of grasslands at this site despite region-wide expansion by creosotebush may be related to the presence and spatial distribution of blue grama-dominated communities that resist woody plant invasion.

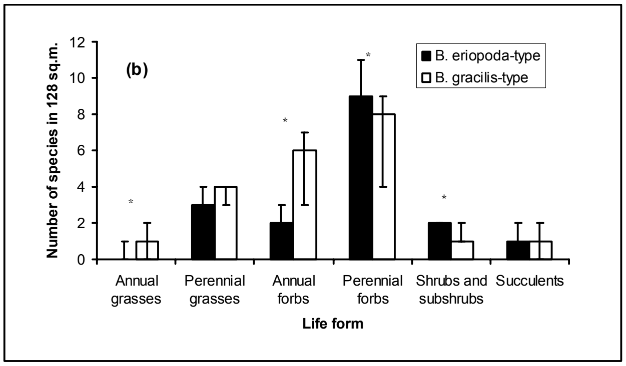


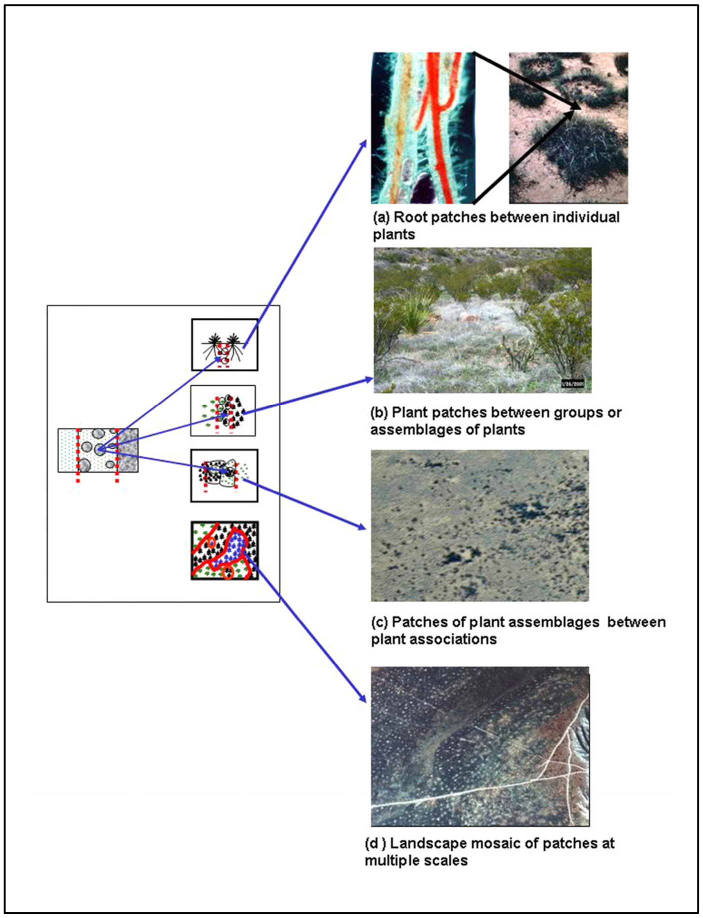
Fig 10. Species composition in blue and black grama patch types.

We continued to analyze the vegetation, soil, and DEM data collected from eight black grama-blue grama transitions, and four creosote-black grama transitions located throughout McKenzie Flats. The following data were collected every 5 m along transects that traversed each ecotone (n=1440): elevation (mm) using a Total Position Station, vegetation cover by species using 0.5 m^2 quadrats, and the GPS coordinates. For two of the four transects, soil samples were collected every 5-10 m from three depths (0-1, 1-5, and 5-20cm). These samples (n=2520) are being analyzed for particle size distribution. We are using the vegetation, soils, and elevation data to test the hypothesis that different kinds of transition zones are found across McKenzie Flats (stable, stationary, shifting), and that these transition zones are controlled by different environmental factors. In addition, a total of 800 blue grama and 400 black grama small patches (< $10m^2$) were measured and geo-referenced.

We also compared the plant species and life form composition of blue grama and black grama patch types at the Sevilleta (Peters et al. *submitted*). Patches were sampled at multiple scales for the occurrence of subordinate species. Association of species with patch type was tested with Chi^2. We also compared our results with the geographic range of each species using floristic manuals and distribution maps to determine if a broader association exists between species and biomes. We found that soils of *B. gracilis*-dominated patches had higher clay and lower rock contents compared with soils of *B. eriopoda*-dominated patches (Fig. 9).Of the 52 species analyzed, most were found associated with one patch type (54%). Sixteen species were associated with *B. gracilis*-dominated patches and 12 species with *B. eriopoda*-dominated patches (Fig. 10). Patches dominated by *B. gracilis* were richer in annuals whereas patches dominated by *B. eriopoda* contained more perennials. Both differences in species characteristics and soil texture between patch types contribute to patch-scale variation and changes in biodiversity across the landscape. Species associated with one of the two patch types occurred across broad geographic ranges. Our results show that patch types at this biome transition zone have characteristic life form and species composition, but the distribution of each subdominant species in these patches cannot be predicted based on its geographic range.

Ecotone conceptual framework. We described an operational framework for understanding and predicting dynamics of these biotic transitions for a range of environmental conditions across multiple spatial scales (Peters et al. *in press*). We define biotic transitions as the boundary and the neighboring states, a more general definition than typically denoted by the terms boundary, ecotone, edge or gradient. We use concepts of patch dynamics to understand the structural properties of biotic transitions and to predict changes in boundaries through time and across space. We developed testable hypotheses, and illustrated the utility of our approach with examples primarily from the Sevilleta (Fig. 11). We discuss three types of ecotones with different dynamics and key controlling factors (stable, shifting, directional). Our framework provides new insights and predictions as to how landscapes may respond to future changes in climate and other environmental drivers.

Fig 11. Conceptual framework of biotic transitions using examples from the Sevilleta and other sites in the Chihuahuan Desert.



Synthesis using simulation modeling. We continue to develop and use a suite of simulation models to address dynamics of arid and semiarid systems. We developed a cellular automata model to simulate landscape scale dynamics across different types of ecotones (stable, shifting, directional) between the three dominant species (blue grama, black grama, creosotebush) at the Sevilleta. The model represents vegetation dynamics under changes in climate and grazing regime through time. In collaboration with the Jornada LTER, we are continuing to modify the ECOTONE simulation model by incorporating the horizontal and vertical distribution of water, nutrients, and soil particles by wind and water across a range of spatial scales, from plants to patches and landscape units. We recently completed the recoding of our soil water model (SOILWAT) into C and C++ to allow easier multi-scale simulations. We are also working with Greg Okin at the University of Virginia to link ECOTONE with his model of wind redistribution of soil particles to allow effects of dynamic vegetation on wind erosion-deposition dynamics. We are also working with Tony Parsons and John Wainwright of England to link ECOTONE with their model of horizontal soil water redistribution across ecotones.

Long term studies of effects of disturbances. We are continuing to examine the effects of small, patchy disturbances on vegetation dynamics at ecotones. We monitor vegetation cover by species annually on 3m x 4m removal plots at five sites located along a grassland-shrubland ecotone on McKenzie Flats as well as a sixth site along the foothills of Los Pinos that represents a predominately blue grama community with very small amounts of black grama and no creosotebush. The five sites have been monitored since 1995 and the sixth was added in 1998. We also added a series of plots with total removals in 2003. Long-term monitoring is needed to determine the species that dominate following the loss of the current dominant.

Consumer dynamics

Ana Davidson (former graduate student, now a postdoc with Gerardo Ceballos at UNAM) and **David Lightfoot** (UNM staff scientist) looked at the keystone role of prairie dogs (*Cynomys* spp.) and banner-tailed kangaroo rats (*Dipodomys spectabilis*) in three grassland ecosystems. Their keystone status is attributed primarily to the effects of their burrowing and foraging behavior. However, these species co-occur in the arid grasslands of the southwestern United States and in Mexico, and differ ecologically in several important respects. We established a cross-site research project that evaluated the comparative and interactive effects of prairie dogs and banner-tailed kangaroo rats in areas where they co-occur at the Sevilleta National Wildlife Refuge, New Mexico, and at Janos, Chihuahua, Mexico (Davidson 2005, Davidson and Lightfoot in press, submitted). We focused our research on the impacts of these rodents on grassland plant and animal communities. We found that vegetation cover, structure, and species richness varied across a gradient extending out from the mound centers, and these patterns differed between prairie dog and kangaroo rat mounds. Certain species and functional groups of plants and arthropods associated differentially with mounds and landscape patches occupied by prairie dogs and banner-tailed kangaroo rats. Where both species co-occurred locally there was greater soil disturbance, more organic material from their feces, and higher activity of other animals, including antelope, rabbits, lizards, and other rodents. The overall effect of prairie dogs and kangaroo rats was to create a mosaic of different patches across the landscape such that their combined activities increased landscape heterogeneity and plant and animal species diversity (Fig. 12).

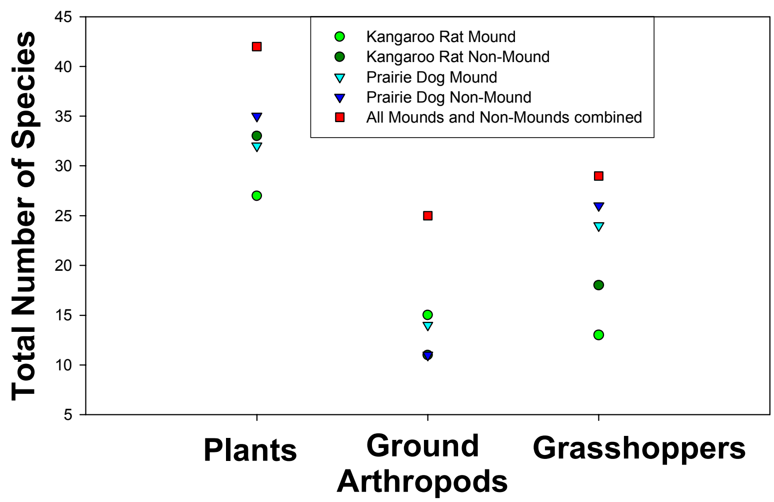


Fig 12. The total number of plants, grasshoppers and other ground-dwelling arthropods on and off K-rat and Prairie Dog mounds at the Sevilleta National Wildlife Refuge. Prairie dog mounds, kangaroo rat mounds, and non-mounds supported different assemblages of plant and arthropod species, and on a per unit area basis, the total accumulated number of species at the mound and landscape-scales was enhanced where prairie dogs and kangaroo rats co-occurred.

Selene Baez, **Scott Collins**, **David Lightfoot** and **Terri Koontz** (graduate student) analyzed data from our long-term small mammal exclosure study established in 1995. Water is widely acknowledged to be the key limiting resource in aridland ecosystems where the amount and timing of precipitation events strongly affect net primary productivity. On the other hand, numerous experimental studies have demonstrated strong consumer control on the composition, production and diversity of aridland plant communities. The mechanisms driving these changes involve consumption of green tissue, seed predation, shifts on species interactions, and alteration of responses to bottom-up inputs. These seemingly contradictory patterns result from non-linear dynamics between rainfall, net primary production and consumers in arid systems which impart high temporal variation in the strength of bottom-up and top-down controls on trophic interactions in aridland ecosystems. Reconciling these competing hypotheses regarding the primacy of top-down and bottom-up controls in aridland ecosystems requires long-term experimental manipulation of consumer and producer communities. To do so, we used a long-term small mammal exclusion experiment designed to evaluate the relative role of bottom-up and top-down controls on plant community structure in low productivity grass- and shrub-dominated Chihuahuan Desert plant communities Baez et al. *submitted*). Specifically, we assessed how bottom-up pulses cascade through vegetation to affect rodent populations and how rodent populations affect plant community structure and dynamics.

We used plant species composition data from 36 permanent 1m2 quadrats in each of four replicate rodent exclosures and open areas in grass- and shrub-dominated vegetation to assess the impacts of small mammals on vegetation dynamics. Rodent abundances outside the exclosures were quantified using data from our core LTER small mammal trapping webs.

We found no significant differences in the cover, species richness, and heterogeneity of grass or shrub vegetation between rodent access and rodent removal treatments (Fig 13). In shrub vegetation, however, plots without rodents had a significantly higher rate of directional change over time compared to sites with rodents (One-way ANOVA, P=0.005, R^2= 0.54, N=8). In grass vegetation, there were no differences in the rate of community change over time for plots with and without rodents (One-way ANOVA, P=0.52, R^2=0.06, N=8).

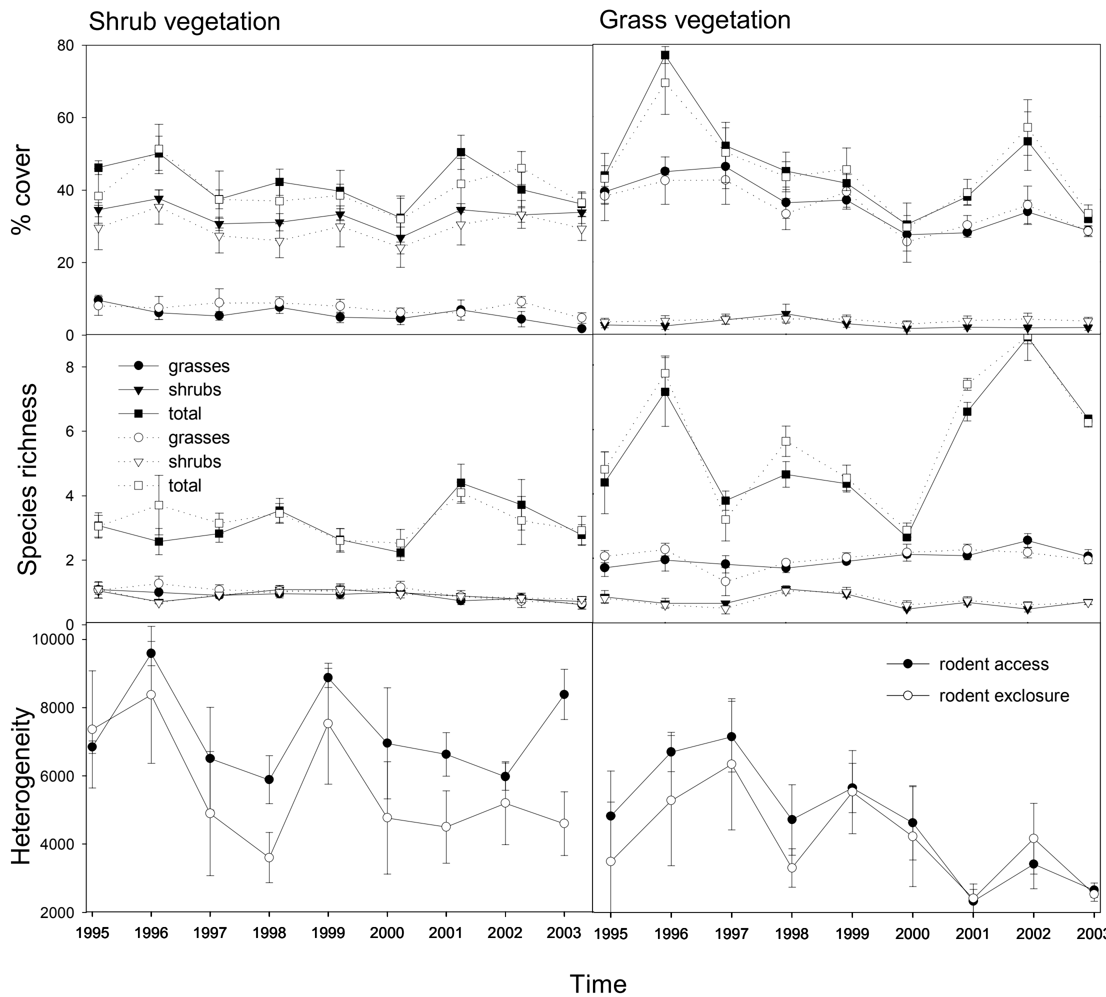


Fig 13. Cover and species richness of functional groups of grass- and shrub-dominated vegetation in rodent removal and control plots.

Overall, we found a positive relationship between precipitation and total cover, and to a lesser extent, diversity of plant functional groups. Cover and diversity in the grassland plots responded positively to summer rainfall, whereas shrub vegetation responded positively to winter rainfall. In only one case did rodent removal affect plant functional type response to seasonal precipitation. In shrub vegetation, control plots had significantly higher heterogeneity compared to rodent removal plots. There were no significant precipitation by treatment interactions.

Precipitation was positively related to consumer density. In grasslands, rodent densities increased in response to summer precipitation of the previous year. Oddly, densities of rodents in grass vegetation were negatively related to the previous year's winter precipitation. This probably resulted from a negative relationship between summer and winter precipitation over the study period rather than a direct reduction of rodent densities due to increased winter rainfall. In shrub vegetation, rodent densities were positively related to summer precipitation of the previous year, and to winter-spring precipitation in the current year.

It is hypothesized that the regulation of plant communities depends on the number of trophic levels of the system, on plant defense resources, and on the level of primary productivity that sustains variable densities of consumers that are interactively controllers or controlled by plants. Characterizing the interactions between producers, consumers, and precipitation is an important step toward understanding the temporal dynamics of bottom-up and top-down regulatory forces in ecosystems. In our arid Chihuahuan Desert system, rodents exerted no top-down control on plant community dynamics, species richness, composition and cover in desert grassland and exerted only minor control in shrub-dominated vegetation. We conclude that bottom-up forces strongly regulate vegetation structure and dynamics in this aridland ecosystem. We suspect that the lack of top-down control results from chronically low rates of net primary production which constrains densities of rodents and other consumers. Whether or not subtle but persistent effects of consumers will eventually lead to changes in community composition in this system remains to be seen.

Andrew Edelman (graduate student) is studying population dynamics and behavior of banner-tailed kangaroo rats (*Dipodomys spectabilis*) on the northern end of McKenzie Flats at the Sevilleta. This summer he began a monthly census and live trapping (3 days/month) of K-rat mounds. The study area is 17.8 ha and contains 147 mounds (8.3 mounds/ha). Over 5 months of trapping, 158 individuals have been marked (females: 37 adults, 42 subadults; males: 26 adults, 52 subadults). Occupancy rate of mounds, based on sign, has fluctuated from a low of 46.3% in March 2005 to a high of 81.7% in August 2005. The large increase in occupancy rate appears to be due to dispersal of subadult kangaroo rats from natal mounds. 12 new mounds have also been built during a 6-month period (8% increase in mounds). Of the 24 subadults where the mother is known, 16.7% have inherited the natal mound after their mother died or disappeared (n = 4), 16.7% have inherited the natal mound after the mother moved to a different mound (n = 4), 29.2% have dispersed to an unoccupied mound (n = 7), and 37.5% have disappeared or remained at the natal mound with the mother (n = 9). Based on live trapping, 75% of adult females (n = 28) and 62% of adult males (n = 16) survived 5 months.

Results from the study on prairie dogs and plague by graduate student **Megan Friggens** of Northern Arizona University show to date that no rodent or flea species collected on the Sevilleta NWR have tested positive for plague. Neither have any of the flea species known to be efficient vectors of plague been found on Sevilleta rodents (Table 1). However, two groups of rodents, *Peromyscus* spp. and *Dipodomys* spp., caught in high numbers on the Sevilleta NWR, are known to be resistant to plague related mortality and have been implicated as maintenance hosts of plague in other ecosystems. *Peromyscus* spp. are found in higher elevation sites on the Sevilleta, while the *Dipodomys* spp. are most concentrated at the site of the prairie dog town. The unique distribution of these rodent species may allow us to define the ultimate role of dispersal in introducing plague to prairie dog colonies. Flea burdens of most rodents appear to be greatest in the spring, which likely corresponds to flea microhabitat (both soil moisture and temperature) requirements (Table 1). No unusual flea-host associations (flea species on non-normal host species) have been found, indicating that a generalist flea species (that feeds on multiple host species) may be required for pathogen transmission between different host species. *Dipodomys spectabilis* carried the greatest diversity of flea species including some generalist species. The dense concentration of *Dipodomys* on prairie dog towns combined with their propensity to carry generalist species of fleas points to the potential role of *Dipodomys* spp. in transferring fleas and pathogens among sympatric rodent species. A closer analysis of the association of *Dipodomys* and *Cynomys* in desert grasslands in conjunction with analyses of the interspecific pathogen transmission between *Dipdomys* and other rodents, may reveal that *Dipodomys* spp. have a huge potential to mediate plague outbreaks in Gunnison's prairie dog populations.

Table 1. Species and prevalence of infestation of fleas collected from 8 rodent species from a prairie dog town on the Sevilleta NWR, New Mexico.

Host	FleaSpecies	Overall Prevalence	Prevalence
Cynomys gunnisoni		0.69	
	Oropsylla hirsuta		0.65
Dipodomys ordii		0.06	
	Meringis arachis		0.06
Dipodomys spectabilis		0.48	
	Echidnophaga gallinacea		0.04
	Malaraeus sinomus		0.04

	Meringis arachis		0.43
Perognathus flavus		0.01	
	Meringis shannoni		0.01
	Orchopeas leucopus		0.01
Peromyscus boylii		0.10	
	Malaraeus sinomus		0.10
Peromyscus eremicus		0.13	
	Orchopeas leucopus		0.13
Peromyscus maniculatus		0.10	
	Peromyscopsylla hesperomys		0.10
Peromyscus truei		0.07	
	Malaraeus sinomus		0.07

Table 2. Flea species collected from 8 rodent species captured during the spring or fall field seasons from a prairie dog town on the Sevilleta NWR, New Mexico.

Host	FleaSpecies	Spring	Fall
Cynomys gunnisoni			
	Oropsylla hirsuta	x	
Dipodomys ordii			
	Meringis arachis	x	
Dipodomys spectabilis			
	Echidnophaga gallinacea		x
	Malaraeus sinomus		x
	Meringis arachis	x	
Perognathus flavus			
	Meringis shannoni	x	
	Orchopeas leucopus		x
Peromyscus boylii			
	Malaraeus sinomus		
Peromyscus eremicus			
	Orchopeas leucopus	x	
Peromyscus maniculatus			
	Peromyscopsylla hesperomys	x	
Peromyscus truei			
	Malaraeus sinomus	x	

Baez, S., S.L. Collins, D. Lightfoot and T. Koontz. Effects of rodent removal on community dynamics in desert grassland and shrubland vegetation. Submitted to *Ecology*.

Cushing, J., K. Vanderbilt, J. Brunt, M. Jones, A. Gupta and P. McCartney. 2005. NSF Long Term Ecological Research Sites: *Praxis et Theoria* -- LTER Information Management and CS Research. Pages 303-307 in J. Frew, editor. Proceedings of the 17th International Conference on Scientific and Statistical Database Management, Donald Bren School of Environmental Science and Management, University of California, Santa Barbara, CA USA.

Davidson, A. D. 2005. The comparative and interactive effects of prairie dogs and banner-tailed kangaroo rats on plants and animals in the northern Chihuahuan Desert. Ph.D. Dissertation. The University of New Mexico.

Davidson, A. D. and D. L. Lightfoot. 2006. Interactive effects of two keystone rodent species in a desertified grassland, Chihuahua, Mexico. Accepted with revision by *Ecography*.

Davidson, A. D. and D. L. Lightfoot. The effects of prairie dogs and kangaroo rats on the structure of grassland arthropod communities. Submitted to *Oikos*.

Kröel-Dulay, Gy., P. Odor, D.P.C. Peters, and T. Hochstrasser. 2004. Distribution of plant species between patch types at a transition zone between two grassland biomes in North America. *Journal of Vegetation Science* 15: 531-538.

Palmer, M.A., E. Bernhardt, E. Chornesky, S.L. Collins, A. Dobson, C. Duke, B. Gold, R. Jacobson, S. Kingsland, R. Kranz, M. Mappin, F. Micheli, J. Morse, M. Pace, M. Pascual, S. Palumbi, J. Reichman, W.H. Schlesinger, A. Townsend, M. Turner, and M. Vasquez. 2005. Ecology for the 21st Century: An action Plan. Frontiers in Ecology and the Environment 3: 4-11.

Peters, D.P.C., J. Yao, and J.R. Gosz. Patch-scale invasion at a semiarid-arid transition zone: implications for landscape scale dynamics. Submitted to *Journal of Vegetation Science*.

Pennings, S.C., C.M. Clark, E.E. Cleland, S.L. Collins, L. Gough, K.L. Gross, D.G. Milchunas and K.N. Suding. 2005. Do individual plant species show predictable responses to nitrogen addition across multiple experiments? *Oikos* 110: 547-555.

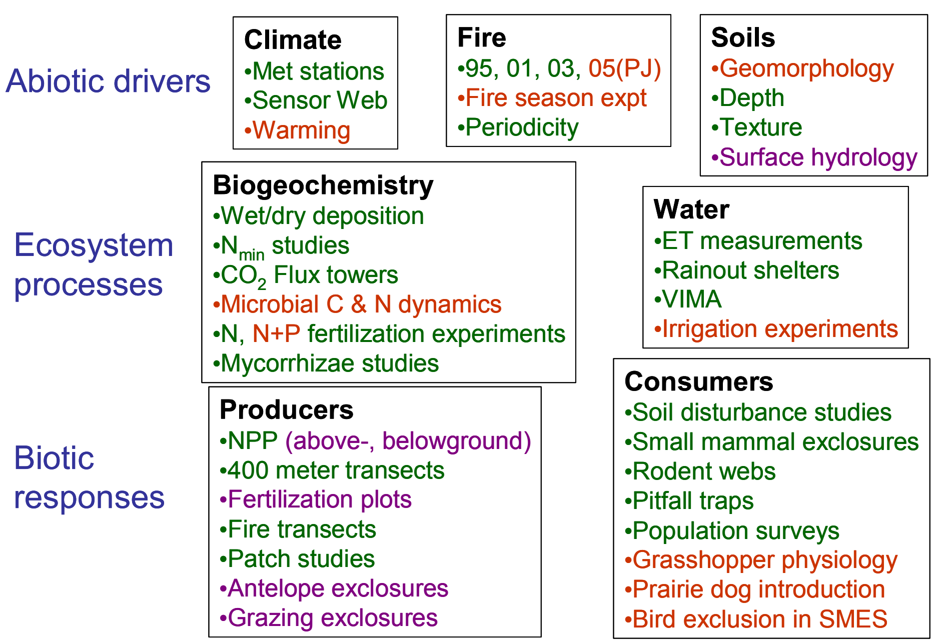
Peters, D.P.C., J. R. Gosz, W.T. Pockman, E.E. Small, R.R. Parmenter, S. L. Collins, and E. Muldavin. Integrating patch and boundary dynamics to understand and predict biotic transitions at multiple scales. *Landscape Ecology*: in press.

Suding, K.N., S.L. Collins, L. Gough, C. Clark, E.E. Cleland, K.L. Gross, D.G. Milchunas and S. Pennings. 2005. Functional- and abundance-based mechanisms explain diversity loss due to N fertilization. *Proceedings of the National Academy of Sciences* 102: 4387-4392.

ACTIVITIES

The overarching goal of the Sevilleta LTER Program is *to understand how abiotic pulses and constraints affect species interactions, community structure and ecosystem processes in arid land ecosystems*. The Sevilleta LTER Program is organized around understanding the individual and interactive effects of three key system components: abiotic drivers, ecosystem processes and biotic responses and feedbacks (Fig 1). In our case, the main abiotic drivers are (1) seasonal, annual and decadal variations in climate, (2) geomorphology, soil texture and depth, and surface hydrology, and (3) season and periodicity of fire. These abiotic drivers affect biogeochemical cycles, particularly nitrogen, phosphorus and carbon, as well as water input, storage, use and loss. Biotic responses to the coupling of these abiotic drivers and ecosystem processes include patterns and controls on net primary production, and the distribution, abundance, diversity and dynamics of plant and animal populations and communities. Although there is considerable research linking primary production and plant community structure, one of the core activities of the Sevilleta LTER is to link climate dynamics, disturbances, and soil structure with soil nutrient and water fluxes to better understand seasonal and annual variability in NPP and its impact on the dynamics, distribution and abundance of key aridland consumers, particularly small mammal populations, lizards and arthropods. Our research program is organized into five main research areas: Climate and abiotic drivers (Cliff Dahm, Group Leader), Soils and biogeochemistry (Bob Sinsabaugh, Group Leader), Water fluxes (Will Pockman, Group Leader), Producer dynamics (Esteban Muldavin, Group Leader), and Consumer dynamics (Blair Wolf, Group Leader). New and continuing research includes a wide variety of activities in each sub-area (Fig 1). This figure, along with our new conceptual framework on multi-scale pulse dynamics in aridland ecosystems, forms the basis of our upcoming renewal proposal. Many of the activities and findings in this annual report reflect our response to the 2003 Site Visit. Major recommendations of the site visit team included expanding and generalizing our conceptual framework, increasing our focus on belowground processes, getting more UNM faculty and graduate students involved in Sevilleta LTER research, and increasing our publication output. We have taken these recommendations seriously and we hope this report reflects our response to the review team's major recommendations.

Fig. 1 Current, New and Planned Sevilleta LTER Research Activities



The Sevilleta LTER Program was particularly active during 2004-2005. During the past year we continued our long term observational studies and manipulative experiments, and we added several new, important observational sites and experimental projects. These activities are briefly outlined below in two sections, Continuing Activities and New Activities. Outcomes of some of these activities are highlighted in the "Findings" section.

Continuing Activities: In the area of **climate and abiotic drivers** we continued to maintain a network of seven comprehensive meteorological stations across the Sevilleta National Wildlife Refuge. In addition, we are now a site in NOAA's Climate Reference Network. Finally, the Sevilleta LTER is serving as a test site for the development of intelligent wireless sensor networks for ecological monitoring, in this case monitoring of microclimate under different species of native shrubs (See Findings). In addition, we received funding from NSF-Ecology (Fargione, Collins, Pockman, PI's) to start a new climate manipulation experiments at the Sevilleta that will determine experimentally the effects of increased nighttime temperatures (especially in winter), increased El Nino events, and increased N deposition on interactions between three dominant species, blue grama, black grama and creosotebush. Also, we just completed installation of infrastructure to allow us to manipulate precipitation pulses (size and interval between events) that will allow us to control, to some extent, precipitation, the key driving variable in aridland ecosystems. This will compliment a recently funded experiment (NIGEC, Pockman and Small, PI's) to increase precipitation inputs by 50% adjacent to the existing rainout shelters that reduce precipitation by 50%.

In the conceptual area of **biogeochemistry and soils**, we continued to measure root and mycorrhizae dynamics in an N-fertilization experiment established in 1995 as part of a cross-site study to determine the effect of N deposition on mycorrhiza-plant interactions. Twelve of the 20 plots had minirhizotrons installed several years ago and we continue to take seasonal readings in these minirhizotrons each year. We continued our monitoring of bulk nitrogen deposition at 11 sites across the Sevilleta and wet-dry deposition at two sites. Soil microtopography and Nmin are sampled seasonally in recently burned (2003) and unburned grassland. We have continued fertilizer applications in our long-term N-fertilization experiment (see also New Activities, below). Finally, we continue to maintain three eddy covariance flux towers (in riparian forest, upland grassland and creosote shrubland) at the Sevilleta. These towers measure CO2 and ET fluxes at each site.

We continue to measure soil water dynamics and ecosystem level **water fluxes** in riparian, grassland and shrubland areas of the Sevilleta via numerous soil moisture probes at the Very Intensive Moisture Array site and the rainout shelter plots located in creosotebush, transition and grassland areas, and at three ET flux tower sites in riparian forest, grass and shrub-dominated areas. We will continue to remove 50% of ambient rainfall in replicated plots in grassland, shrubland and transition areas to induce drought and assess the impacts of severe drought on plant physiology and various ecosystem processes (Fig 2). In addition, our new rainfall pulse, 50% water addition and nighttime warming experiments will add to our general understanding of soil water dynamics and ecosystem processes.

Fig 2. Rainout shelters in creosote-dominated shrubland. Similar shelters are located in black grama dominated grassland and in a grass-shrub transition zone. Water addition plots are located behind the rainout shelters.

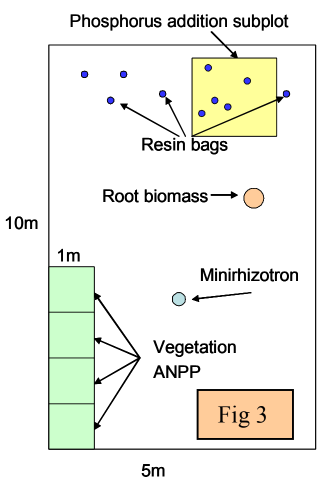
In the area of **producer dynamics**, we continued to measure vegetation composition and structure along two 400-m long permanently located line intercept transects on McKenzie Flats. Data from 1989-2003 were analyzed and presented by Collins et al. at the 2004 ESA Annual Meeting in Portland, OR. In addition, we continued to measure vegetation composition along four 100-m long permanently located line intercept transects that cross a burned-unburned boundary from a wildfire in 1995. We continue to measure plant community composition in grassland and shrubland areas with and without rodents (See Findings), and we continued to maintain and measure plant species and functional group removal experiments (See Findings). In addition, we measure ANPP at our core blue grama, black grama and creosote sites, and we measure belowground root and mycorrhizae dynamics in minirhizotrons in the N fertilization experiment, mixed grass-dominated vegetation near Deep Well, creosote-dominated vegetation near Five Points, mixed grass-shrub vegetation in the rainout shelters, and under fertilized and unfertilized piñon and juniper trees in the Los Piños Mountains.

Continuing measurements of **consumer dynamics** include small mammal and arthropod pitfall traps in blue grama, black grama, creosote, and piñon-juniper sites, and grasshopper populations in grassland, grass-shrub transition and shrub-dominated sites. We also monitor coyote and rabbit abundance on McKenzie Flats. One of the unique activities of the Sevilleta LTER is our long-term monitoring of native bee populations in desert grasslands spearheaded by the head of our field crew, Karen Wetherill, in collaboration with Burt and Rose Pendleton of the USFS Rocky Mountain Research Station in Albuquerque.

New Activities: In the area of **climate and abiotic drivers** we will be installing a new Sensor Web 5.0 network to monitor microclimate variation in our new nighttime warming, El Nino, N-deposition experiment funded by NSF-

Ecology and EPSCoR. Sensor Web 5.0 is a much improved system of wireless sensors developed by Kevin Delin and colleagues at NASA's Jet Propulsion Lab. Wireless sensor networks are not passive dataloggers without wires, instead, they can be programmed to perform QA/QC and activation algorithms, among other duties, on the fly (See Findings). The new experiment where we will install the Sensor Web 5.0 is designed to manipulate key climatic drivers that will ultimately affect microclimate, precipitation and soil moisture dynamics and nutrient availability in a system that is chronically low in water and nitrogen. This experiment links with producer dynamics in that it is designed to determine if predicted changes in rainfall, nitrogen and temperature will increase the rate at which woody vegetation, particularly creosotebush, will invade and eventually replace grass-dominated vegetation.

Water fluxes: Using start-up funds provided by UNM to PI Collins, we are installing a replicated field experiment that will allow us to control the size and frequency of monsoon rainfall pulses in desert grassland. Treatments will include ambient rainfall (reference plots), and plots which receive (1) one large rainfall event each month, (2) two medium-sized rainfall events each month or (3) small, weekly rainfall events. Each of the three rainfall addition treatments will receive the same amount of total rainfall by the end of the monsoon season (July-Sept). Subplots in each treatment plot will receive N fertilizer at a rate of 5gNm-2 in two 2.5g applications each year to allow us to determine how rainfall pulses interact with N dynamics to affect soil C fluxes, community composition and annual aboveground NPP. This experiment is co-located with, and will compliment data from, existing infrastructure that either removes 50% ambient rainfall from replicate plots or increases ambient rainfall by ca. 50% each year (Fig 2).



Biogeochemistry and soils: We have greatly enhanced our research activities in our long-term N-fertilization plots (Fig 3). In 2005, we received "proof of concept" funding from NSF-Ecosystems (Sinsabaugh, Collins, Allen, Hanson, PI's), to investigate the role of fungi in the N cycle of these arid grasslands (See Findings). In addition, we now measure plant species composition, above- and belowground NPP, N and C availability, and extracellular enzyme activities in treatment and control plots. We have also added P-addition subplots within the N fertilization plots so that we can determine the relative roles of N and P in this aridland ecosystem. Increasing our activities in these plots allows us to tie into an important LTER cross site synthesis of fertilization effects on plant community structure and dynamics (Suding, Collins et al. 2005, Pennings et al. 2005). Bryan Brandel, a graduate student at the University of Colorado, is studying N and C dynamics across the grass- to shrubland ecotone. This work will allow him to use remote sensor to scale up N and C processes at the Sevilleta. In addition to our nutrient amendment experiments, two graduate students from the Department of Earth and Planetary Sciences at UNM started to characterize the geology and geomorphology of the McKenzie Flats area, one of our main study areas at the Sevilleta, using a series of deep soil trenches (See Findings).

Producer dynamics: In 2004-5 we initiated collection of plant species composition in 48 permanently located quadrats in two experiments that were initially established in 1993 but lacked consistent vegetation collection protocols. The first experiment addresses the effect of grazing on plant community dynamics in desert grassland. Three replicate 300x300m exclosures were established in a grazed pasture north of the Refuge boundary. These exclosures were paired with three sample areas open to grazing by domestic cattle. In addition, there are three similarly sized sample areas inside the Refuge boundary. This allows us to measure the short-term and long-term recovery dynamics of grasslands following grazing by domestic cattle. Soil N dynamics and standing crop are also measured annually in each treatment. In 2004 we also initiated a similar sampling protocol in another experiment with and without browsing by native antelopes. This experiment has four replicates of the following treatments burned in 2003 or left unburned, fully crossed with open to antelope browsing versus no antelopes.

In 2004-5, we expanded our NPP measurements from only three core areas to ten sites, including burned and unburned grassland, transition, and creosote-dominated shrubland. We also resumed NPP measurements in the herbaceous layer in Piñon-Juniper woodland at Cerro Montosa. Because our NPP measurements are based on non-destructive allometric estimates by species (same as Jornada LTER), we also get accurate long-term measurements of plant community composition at our NPP sites. We added a new sampling protocol in which we now measure belowground standing crop at all sites where we measure aboveground production. In addition, we installed root ingrowth donuts at five sites co-located near minirhizotron arrays as well as in the N-fertilization plots.

Joanna Redfern (graduate student) in collaboration with **Burt Pendleton** (USFS Ecologist) and **Etsuko Nonaka** (graduate student) are in the process of mapping populations of creosotebush (*Larrea tridentata*) and ocotillo (*Fouquieria splendens*) for long term studies of plant population dynamics at the Sevilleta. Nine 20m^2 plots have been established to monitor creosotebush near the Five Points area. The design includes three sets of three plots, where each set of plots includes a low, medium, and high density plot. All of the low and medium density plots and one high density plot have been surveyed this year to determine the number of plants in the plots, and the exact location of each plant within the plot. Three plots (low, medium and high density) were established to monitor ocotillo population dynamics. The steep rocky terrain on which ocotillo grows precludes using the same technique as is used to survey creosotebush plants. GPS will be used to survey ocotillo within these plots. A system to convert the raw location data for each plant in a plot into a stem map for the plot is being developed. For the demographic study of ocotillo size classes (i.e. small, medium, large) are being identified to identify which plants to use to relate size to biomass. The size classes are based on height measurements made in 2003.

Consumer dynamics: In 2005 we initiated an exciting new experimental restoration of Gunnison's prairie dogs at the Sevilleta. Through the hard work of Sevilleta staff and graduate students in partnership with USFWS, private foundations, and a prairie dog restoration specialist, 99 artificial burrows were constructed at the SEV to create three replicate prairie dog colonies with approximately 110 animals added to each new colony. Each replicate colony is paired with a prairie dog-free reference area. Planned long term measurements include plant species composition, above- and belowground standing crop, soil nutrient dynamics and, of course, prairie dog population dynamics.

Soil excavation for artificial prairie dog burrows at the Sevilleta National Wildlife Refuge as part of our new Gunnison's prairie dog restoration experiment. Ninety-nine burrows were excavated by backhoe. A total of 327 prairie dogs was introduced in three replicate colonies on the north end of McKenzie Flats.

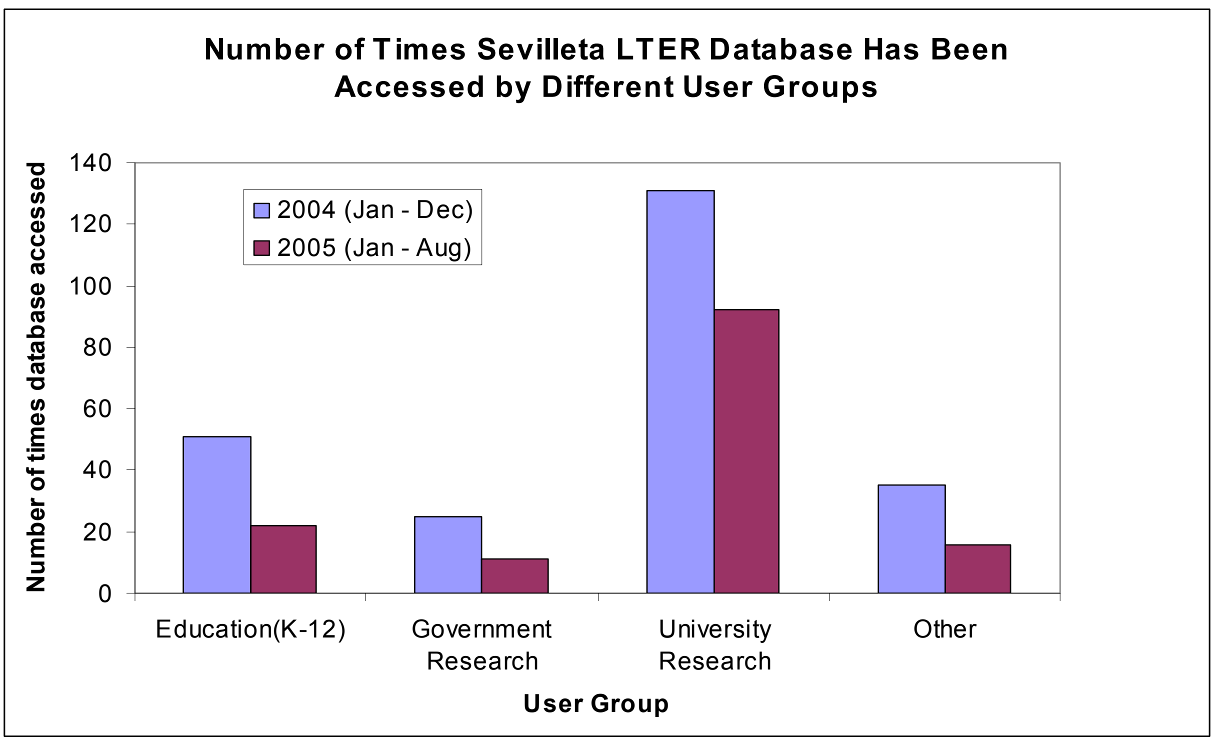
In addition to our restoration experiment, **Megan M. Friggens**, a graduate student at Northern Arizona University, is studying plague ecology of Gunnison's prairie dog to determine if a rodent mediated mechanism exists for plague epizootics. This project is designed to assess whether climate driven-dispersal events of plague (*Yersinia pestis*) reservoir hosts cause plague epizootics in Gunnison's prairie dog (*Cynomys gunnisoni*) colonies. In particular, we examine the relationships between weather patterns (precipitation), vegetation production, rodent and flea densities, prevalence of pathogens within host and vector, and interspecific contact between potential rodent carriers and the prairie dogs inhabiting the Sevilleta National Wildlife Refuge. Another vector-transmitted blood-borne bacterium, *Bartonella,* is also being surveyed from the small mammals captured in this project. *Bartonella* are generally less pathogenic and more frequently (often >50% prevalence) found in their mammal hosts than *Y. pestis.* Thus, *Bartonella* will be used to study interspecific transmission dynamics in the potential absence of plague outbreaks on the Sevilleta. Though several rodent species have been implicated as potential reservoir hosts of plague, no research has assessed the role of these potential reservoir species or their fleas in introducing plague into prairie dog colonies. Since May 2004, surveys have been conducted each spring and fall of the rodents inhabiting a prairie dog town on the Sevilleta and blood and flea samples have been collected from each animal to test for the presence of plague and *Bartonella*.

Tim Meehan (former graduate student and now an Assistant Professor at College of Santa Fe), **Blair Wolf** (LTER-CoPI) and **Casey Gilman** (REU) are in the process of studying carbon and nitrogen turnover in lizard tissues in relation to their metabolic rates. Lizards are important secondary and tertiary consumers in Southwest ecosystems. Stable isotope analysis of lizard tissues can be used to understand the specific roles of lizards in material and energy flux. Interpreting stable isotope data on lizard resource use requires an understanding of isotopic fractionation factors and turnover rates. A diet switching experiment is being conducted to learn how these quantities are related to individual metabolic rate, which is in turn related to an organism's body mass and temperature. This project is still in progress and is expected to continue until spring of 2006. To date, lizards have been collected, housed, and fed a baseline diet with a known isotopic profile. The next step is to switch their diet to one with a different isotopic profile and make a series of measurements of carbon and nitrogen isotopes in their tissues. The diet switch occurred in summer 2005.

In a related study, Graduate students **Alaina Pershall** and **Robin Warne** and CoPI **Blair Wolf** are using stable isotopes to study foodweb dynamics in the creosote-grassland transition zone near Five Points at the Sevilleta. They sampled rodents, lizards, arthropods and vegetation for stable isotope analysis of carbon and nitrogen. Because C3 and C4 plants have growth responses during different seasons, we expect to see a shift in the carbon isotope signal of the sampled organisms reflecting the changes in the vegetation from C3 plants in the spring to C4 in the fall. Twelve pitfall trap arrays with drift fencing were installed this summer for catching lizards, and small mammals were sampled monthly on two rodent trapping webs. All arthropods found in the pitfall traps were collected and grasshoppers were also collected with nets and will be processed for stable isotope analysis. Blood samples from lizards and rodents were collected monthly for stable isotope analysis. This work will continue through 2005 and 2006 growing seasons. Results of the stable isotope analyses are pending.

Information Management

With the assistance of Inigo San Gil of LNO, approximately 40% of the Sevilleta LTER's legacy metadata has been converted into Level 3 or better Ecological Metadata Language (EML), the LTER Network's metadata standard. Sevilleta EML files are being harvested to a centralized Metacat database (http://prairie.lternet.edu:8080/query). This will greatly facilitate the discovery of Sevilleta data.



Updates to the Sevilleta LTER website include the addition of a Wiki to the Intranet, where an IM Handbook is being created. Webmail is now also available via the Intranet, as is an interface where researchers log their visits to the Sevilleta NWR.

The Sevilleta LTER bibliography database was transferred from a text file to the Sevilleta MySQL database. A web application was also created by programmer Harsha Belludi for searching the Sevilleta bibliography and adding new records.

A much-needed backup system for the Sevilleta Sun E450 server was installed in January 2005.

Extracurricular activities:

Kristin Vanderbilt, Sevilleta IM, has served as information management liaison to the Biogeochemistry Committee for the Network Planning Grant. She contributed a poster entitled: "Ecoinformatics Training: Toward Data Sharing and Collaborative Research" to the NSF sponsored workshop "Enhancing Collaborative Research on the Environment in Sub-Saharan Africa (SSA)". Kristin also co-organized a panel discussion at the 2005 Statistical and Scientific Database Management (SSDBM) meeting (Cushing et al. 2005). She is collaborating on a research project with Judy Cushing of Evergreen State College wherein templates for grassland NPP databases are being developed to facilitate data synthesis across LTER sites. Kristin co-taught a week-long ecoinformatics workshop for personnel from the Organization of Biological Field Stations (OBFS), an annual event. As a collaborator on the Science Environment for Ecological Knowledge (SEEK) project, Kristin also co-taught an ecoinformatics workshop for post-docs and junior faculty.

The Sevilleta Research and Education Center, Sevilleta National Wildlife Refuge, New Mexico. A consortium of UNM, NM Tech, NMSU, Sandia and Los Alamos National Labs have integrated and focused their research efforts to address important environmental issues in the state and integrate this research with public education over a broad range of disciplines. A key to the success of this effort is the addition of a Research and Education Center to the Research Field Station on the Sevilleta National Wildlife Refuge (NWR) in Socorro County, New Mexico. *The location in central New Mexico and in the natural environment of a wildlife refuge is key to providing a common base to attract and organize researchers and educators from throughout the state and Southwest Region.* Scientists, resource managers and students from many disciplines will use the facility to plan and carry out multi-disciplinary studies throughout the Rio Grande Valley of New Mexico. Center research capabilities will include laboratories for plant and animal studies, soil and water analyses, genetic studies, microbial research, biodiversity mapping, and infectious disease research. Access to state-of-the-art high performance computing and data management will allow integration of myriad databases generated by Federal, State and University researchers. This integration is needed for the successful incorporation of our scientific understanding to natural resource management activities. There are many independent data generating activities within the state but they are *not* well integrated. Teaching and public outreach facilities will disseminate the information to K-12 students and the general public. The new Center will contribute to:

- **Scientific research for multi-disciplinary projects** – The Sevilleta NWR currently hosts many active research programs and this new facility will allow the needed expansion of research required to better understand environmental issues throughout the broader Rio Grande Basin. These studies will lead directly to "applied" results for society – for example, predictions of human disease outbreaks (hantavirus, plague) based on ecosystem responses to El Niño weather patterns, improved hydrologic data for the Rio Grande that will aid policies on water allocation, habitat needs for aquatic and riparian species (e.g., Silvery Minnow, Willow Flycatcher), and estimating agricultural, range and timber production from satellite-based spectral sensors. New technologies in remote sensing will allow real-time mapping of changes in these patterns and rapid-response capabilities. This also will allow testing of new technologies developed by university and national lab research.
- **Research on management issues involving public lands** – Land management strategies will continue to evolve as social pressures on public natural resources increase. Researchers in the Rio Grande Basin of New Mexico need to work together to address the complexities of human activities and economic development on natural resources and ecosystem health. Given the Sevilleta NWR's history of environmental research and its central geographic location in the New Mexico's Rio Grande Basin, the refuge is ideally suited to become a central hub for research on such topics as range and wildlife management, conservation strategies for endangered species, removal of problem species (e.g., salt cedar), human land use patterns, fire ecology, and ecosystem responses to climate change.
- **Attracting world-class scientists** – Hundreds of scientists/students have been attracted to the science conferences and research capabilities on the Sevilleta NWR over the past decade. This will increase with the new facility and add markedly to the expertise and information available for resource managers, policy-makers and educators. The capabilities also attract other agency research efforts (e.g., NASA validation studies for satellite sensors, ARS research on fire).
- **Public dissemination of research results** – Much of the data generated by government and university researchers remains inaccessible or incomprehensible to the general public. Researchers at the Sevilleta Center would integrate these data, and make them available for public groups and individuals. The Sevilleta NWR has functioned as "neutral ground" for opposing public interest groups (environmentalists to ranchers), and the

expanded Center's facilities will enhance the role of the consortium of institutions in providing a rational scientific basis in public debates on issues of public importance in New Mexico. Conferences at Sevilleta also provide a "neutral ground" atmosphere.

- **Public education** – The proposed Sevilleta Center will provide vastly expanded educational opportunities for K-12, undergraduate and graduate students, and science training opportunities for teachers. Involving students and teachers in research "*in the field"* is critical to the success.

UNM Sevilleta Field Station SMPC Architects