# Sevilleta LTER 1999 Annual Report


## James R. Gosz, Principal Investigator


## Sevilleta LTER II: Biome-level constraints on population, community, and ecosystem responses to climate fluctuation. (DEB 9411976)


**Summary**

The Sevilleta LTER Program has continued investigating the role of climate dynamics as a major driver of ecosystem processes in the biome transition zones of central New Mexico. The 1998-1999 period included the very strong El Niño during the winter-spring of 1998, followed by the unusually dry winter-spring La Niña of 1999. The dynamics of both plant and animal populations during these events followed predicted patterns determined from earlier Sevilleta LTER studies; vegetation and net primary production responded positively to the increased precipitation of the El Niño, and negatively to the drier La Niña, while small mammal populations exhibited the predicted one-year lag following the El Niño before increasing. This latter dynamic was used in warning the public in 1998 of increased risk of hantavirus disease prior to the actual outbreak in 1999. The above-average rainfall received during this summer's monsoon season has led to an exceptional increase in plant growth; this pattern was similar to that observed during the monsoons of 1996, which also followed a La Niña (1995-1996). The Sevilleta LTER research group has continued to develop landscape-level models of precipitation redistribution (model SPLASH) to be integrated with landscape patterns of NPP and vegetation change. Coupled with studies on nutrient inputs from wetfall/dryfall, nutrient cycling rates and patterns, vegetation responses to moisture dynamics, and animal population fluctuations through time and space, the landscape models are providing the basis for integrating the various processes that dictate the structure and functioning of the desert-grassland-woodland ecosystems of the Sevilleta region.

Specific accomplishments of the past year include: (1) the consolidation of several scattered field study sites in a spatially tighter set of intensive research areas representing the four major Sevilleta ecosystems (Chihuahuan Desert, Great Plains grassland, juniper-oak savanna, and piñon-juniper woodlands); (2) initiation of new NPP studies at these study sites; (3) use of remote-sensing data to characterize woody plant patterns in grassland transition zones; (4) an analysis of tree-ring patterns of Sevilleta piñon pines that revealed 700 year records of precipitation, and identified patterns of drought and juniper/piñon mortality and recruitment; (5) field experiments revealing that the effects of nitrogen limitation on NPP and plant cover are species-specific, and interact with rainfall to produce a mosaic of responses within the community; (6) an evaluation of diversity patterns and fractal relationships within and among the major vegetation communities, with multiple mathematical approaches yielding different insights to underlying patterns; (7) an analysis of 20 years of vegetation change on the Sevilleta National Wildlife Refuge (NWR), beginning with

the period immediately following the removal of livestock and prairie dogs in the mid-1970's; (8) a suite of detailed manipulative experiments to evaluate the relationships among plant species in the desert-grassland transition zone, which address interspecific competition, animal disturbances, seed production, germination and recruitment and the role of woody plants in facilitating changes in grassland species composition and dominance; (9) a pattern analysis of meso-scale soil characteristics showing the relationships with the associated grassland plant communities; (10) continued experiments on plant litter decomposition, patterns of nitrogen mineralization, and soil erosion; (11) detailed analyses and experiments on the role of shrubs in creating "islands of fertility" as they invade the Sevilleta NWR grasslands; (12) continued population studies of arthropods and mammals, with their predicted responses to climate fluctuations; (13) detailed diet studies of rodents and coyotes in Sevilleta NWR populations, to test for prey switching behavior as a potential regulating mechanism for population dynamics; (14) a synthesis of the rodent parasite database, examining patterns of host-parasite relationships for major parasite taxa over the four major ecosystems and the 10 years of Sevilleta LTER data collection; (15) the continuation of the small mammal exclosure study to examine animal effects (herbivory, soil disturbance, competition with ants and other insects) on desert and grassland ecosystem processes; (16) an analysis of plant and animal data from Sevilleta fire experiments, and the planning of future experiments on fire ecology in 2000 when the U.S. Fish and Wildlife Service begins to conduct management burns in portions of the Sevilleta NWR; (17) the beginning of a new detailed study of a natural recolonization by Gunnison's prairie dogs into the Sevilleta NWR; (18) a collaborative study on water budgets of the Rio Grande valley, particularly with respect to AET in the riparian forests during natural and managed flooding events; and (19) continued cross-site studies with Mexico (Mapimi MAB site), Jornada LTER site, Bandelier National Monument and Los Alamos National Laboratory, and the Hungarian LTER Program, and collaborative cross-site studies on mycorrhizal fungi and below-ground root population dynamics. In addition, the Sevilleta LTER research group continues to participate in educational activities and public outreach, working with K-12 schoolchildren at the Sevilleta Research Field Station, the New Mexico Museum of Natural History, the Schoolyard LTER Program, and the NSF Research Experiences for Undergraduates Program. Complimenting the Sevilleta LTER program, LTER scientists currently have been awarded over 20 additional grants, with over $13.5 million in research funding. Finally, during this most recent reporting period, the Sevilleta LTER group has published 46 papers, book chapters, and reports.

## I. The Sevilleta LTER Program

*Overview.* The Sevilleta Long Term Ecological Research Program (LTER) was initiated in October, 1988, and has focused on a suite of ecological hypotheses concerning climate dynamics and the responses of organisms in a biome transition zone in central New Mexico. The Sevilleta LTER research region straddles several major biomes of the Southwest, and the large geographic scale of the Sevilleta region is important for studies that range from genetics and physiology at the organismal level, to the dynamics of biome transition zones. The region is strongly influenced by the El Niño Southern Oscillation (ENSO), with major fluctuations in precipitation on semi-decadal time scales. During the 1998-99 reporting year, 46 LTER research papers have been published or are in press.

*Program Organization*. In the fall of 1997, Dr. James Gosz returned as the P.I. of the Sevilleta LTER Program, and the 1998-99 period has been one of synthesizing many of the ongoing Sevilleta research data sets. The LTER program still has a major emphasis on the use of the energy/water balance landscape models as an integrating framework for the numerous ongoing studies. Two additional post-doctoral associates were hired in the fall of 1998, one to work on watershed-level evapotranspiration models, and the other to link plant NPP and physiological patterns with remotely-sensed imagery. A major group emphasis on improved integration of the various LTER studies has been accomplished, and this September we will have completed the first year of direct field measures of NPP in each of our major ecosystems: Chihuahuan Desert, Short-Grass Steppe, Juniper-Oak Savanna, and Piñon-Juniper Woodland. Data management efforts have continued to upgrade the Sevilleta Information Management System and make it Y2K compliant. In addition, the updated Internet homepage has continued to grow with more of the long-term databases coming on line. All Sevilleta LTER program descriptions and data sets can be viewed at: **http://sevilleta.unm.edu/**

## II. Research Activities

The overall research scheme of the Sevilleta LTER is organized around the relationship of energy and water as limiting factors for ecological processes in the various ecosystems of central New Mexico. The dynamics of energy and moisture inputs at various spatial and temporal scales serve as drivers (both direct and indirect) for the observed patterns and dynamics of Sevilleta's ecosystems, communities, and populations. We have been developing a series of models that can simulate biological responses to moisture and energy inputs on various scales (from sub-hectare plots to the 100,000 ha Sevilleta National Wildlife Refuge). Once parameterized and calibrated through field measurements and experiments, these models will permit the development of predictive scenarios in which future ecological responses to climate dynamics can be evaluated. The models will rely on inputs from our meteorological and hydrological studies, vegetation studies, GIS data layers (soils, vegetation map), remote sensing and ground-based NPP measurements, nutrient cycling dynamics, and the interaction studies of important populations of herbivores, predators, and detritivores. The following sections report the most recent progress in each of these areas.

**List of Research Activities:**



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## A. Meteorology Studies

*Climate data from Sevilleta meteorological stations (Doug Moore)*

Climate/meteorological efforts during the past year have primarily centered on maintaining the network of 7 weather stations on the Sevilleta Wildlife Refuge. Aging of the systems has necessitated increased maintenance and calibration time. In addition, the decision to consolidate all flora and fauna studies on the east side of the Sevilleta refuge, with emphasis being exerted to study the transition zones between the desert shrublands and grasslands, and the juniper-oak savanna and piñon-juniper woodland, required that new stations be established to better monitor the micro-meteorological differences across these transitions. To that end two new station were established, the first at the lower Goat Draw/Blue Springs area and the second at the Five Points desert shrubland to grassland transition area. These stations have been equipped with the basic array of meteorological sensors that exist on the other stations. Soil moisture monitoring equipment for these new sites is still in the process of being purchased and installed or transferred from other sites.

With 10 full years of meteorological monitoring database management continues to be a major part of the meteorological effort. Efforts continue to increase meteorological/climatological information available on the Network. This includes both raw data and daily, monthly and annual summaries. This information can be accessed via the Sevilleta - Climate Meteorology Home page at the following URL: **http://sevilleta.unm.edu/research/local/climate.** Work also continues to get all of the data from all of our weather stations incorporated into the LTER network's centralized database – climDB.

*Precipitation Chemistry (Doug Moore)*

With the refocusing of work on the Sevilleta transition zones it was decided that increased monitoring of precipitation chemistry across these zones would also be useful. Collecting funnels were installed in conjunction with each of the new meteorological stations. This increases the number of sites being monitored for precipitation chemistry to 8; there are still 21 sites at which funnel gauges are still being used to measure precipitation inputs.

*Estimation of Evapotranspiration Rates (James Cleverly, Doug Moore, Cliff Dahm and James Gosz).*

Two projects on the Sevilleta NWR are ongoing which address evapotranspiration (ET), mesoscale transport of energy, and the interactivity of terrestrial ecosystems and the atmosphere. First, a Bowen Ratio Energy Balance System has been deployed in the Short-Grass Steppe site at Deep Well on McKenzie Flats. Evapotranspiration is estimated from the solution of the energy balance equation, where incoming net radiation is equal to the sum of latent heat flux, sensible heat flux and ground heat flux. The tower has been under operation during the growing seasons of 1997, 1998 and 1999, and the data from 1998 have been thoroughly analyzed. ET rate peaked at 200 W $m^{-2}$ during the July monsoons, during which time the closest relationship between rainfall and precipitation occurred. A manuscript detailing these results is in preparation: Cleverly, J.R., D. Moore and J.R. Gosz. Seasonal patterns of wind structure and Bowen Ratio derived evapotranspiration in a Chihuahuan Desert grassland, Sevilleta LTER, New Mexico.

Connected to McKenzie flats through the atmosphere is the Rio Grande Bosque (riparian) ecosystem. Evaluation of the landscape-level relationships between the atmosphere and these closely-connected ecosystems was performed by comparing the 3-dimensional eddy covariance derived ET rate from the *Tamarix ramosissima* dominated riparian forest to the grassland site, both on the Sevilleta NWR. In this NASA-funded research project, it was found that the western half of the Sevilleta NWR is a source of energy (to be used in ET or heat flux) during the spring, and the eastern half of the Sevilleta NWR (where the Bowen Ratio tower is located) was a source of heat energy during the summer. Unlike ET in the grasslands to the east of the Bosque, ET in the riparian forest is unresponsive to precipitation. ET in the Bosque is dominated by flooding, with maximal ET rates of 400 W $m^{-2}$ occurring during the spring flooding of early June. A manuscript detailing the preliminary estimates of Middle Rio Grande ET is in preparation: Cleverly, J.R., D. Gilroy, J. Thibault, P. Unnikrishna and C.N. Dahm. A preliminary estimate of actual evapotranspiration from *Populus deltoides* ssp. *wislizenii* and *Tamarix ramosissima* stands with implications for the Middle Rio Grande water budget.

*Decadal climatic variability and ecological responses (Tom Swetnam and Julio Betancourt)*

Ecological responses to climatic variability in the Southwest include regionally-synchronized fires, insect outbreaks, and pulses in tree demography (births and deaths). Multi-century tree-ring reconstructions of drought, disturbance history, and tree demography reveal climatic effects across scales, from annual to decadal, and from local to mesoscale ($10^8$ to $10^{11}$ $km^2$). On the Sevilleta NWR, episodic dry and wet episodes have altered age structures and species composition of woodland and conifer forests. The scarcity of old, living conifers established before ca. 1600

suggests that the extreme drought of 1575-1595 had pervasive effects on tree populations. The most extreme drought of the past 300 years occurred in the mid-twentieth century (1942-1957). This drought resulted in broadscale plant die-offs in shrublands, woodlands, and forests, and accelerated shrub invasion of grasslands. Drought conditions were broken by the post-1976 shift to the negative ENSO-phase and wetter cool seasons in the Southwest. The post-1976 period shows up as an unprecedented surge in tree-ring growth within millennia-length chronologies. This unusually wet episode may have produced a pulse in tree recruitment and improved rangeland conditions (e.g., higher grass production), though additional study is needed to disentangle the interacting roles of land-use and climate. The results of the Sevilleta tree-ring studies have been published in Swetnam and Betancourt (1998).

## B. Landscape Modeling

*Water balance model and parameterization (Bruce Milne and Scott Martens).*

We have continued our efforts to implement a daily time step water balance model for the 1.08 million 30-m cells that compose the Sevilleta has continued. In 1998, we completed a detailed vegetation map for the 100,000 ha site. Map products include estimates of plant community types (both using a site-specific classification and the IGBP method of Steven Running), plant height, plant cover, and leaf area index. The maps were constructed using 12 Landsat TM images and over 200 field plots collected jointly with the New Mexico Heritage Office from 1994-1996. Ongoing development of the model, SPLASH (see below), by Dr. Scott Martens uses the vegetation maps as inputs. A preliminary version of the model uses spatially distributed precipitation estimates, vegetation, soils, temperature, and solar radiation to model potential evapotranspiration, actual evapotranspiration, and water deficit. In the near term, these variables will be used to estimate net primary productivity. Analyses of the vegetation and LAI maps have provided evidence for nonequilibrial processes in the Sevilleta (Milne 1998) and for explorations of scaling issues related to forthcoming sensors such as MODIS (Milne and Cohen, in press).

*SPLASH Model Description (Bruce Milne and Scott Martens).*

The spatially explicit hydrologic model SPLASH (Simulator for Processes on Landscapes: Surface/subsurface Hydrology) has been implemented for the Sevilleta. SPLASH was extensively modified from its original form to take advantage of existing Sevilleta data sets, better simulate arid land hydrology, and run at a daily time step. This new version is called SPLASH-DAY to distinguish it from the original SPLASH, and to highlight the daily time step that it uses. SPLASH-DAY does not explicitly calculate lateral surface and subsurface flows like the original SPLASH.

Simulations of soil moisture from SPLASH-DAY compare favorably with data from time-domain reflectometry. Summer soil moisture is highly dynamic and SPLASH-DAY simulations track this variation well. However, SPLASH-DAY simulated soil moisture slightly lags the measured values during periods of soil drying. Preliminary comparisons of SPLASH-DAY simulated evapotranspiration (ET) with that from Bowen station measurements (prepared by James Cleverly) indicate that SPLASH-DAY underpredicts ET at the high extreme. These high ET values (from Bowen ratio) appear to occur on days with precipitation or the day after. The discrepancy between simulated and measured ET is being investigated. Currently, it is thought that the Bowen ratio data

for high ET days may reflect short duration (hours), high water vapor fluxes ("spikes" in ET). SPLASH-DAY misses these spikes because its fundamental time step is one day. Thus, it uses time-averaged meteorological data to drive ET calculations, and time-averaged soil moisture to calculate soil resistance to evaporation. Both of these conditions could lead to underestimates of ET during, or shortly after, precipitation events. If this is shown to be true, it may also account for the lag in simulated soil moisture during soil dry-down.

The model testing described has used site-specific soil characterizations (physical parameters derived from soil depth, soil texture, stoniness) when running SPLASH-DAY. However, soil physical parameters for the Sevilleta LTER region are derived from the maps and data in the Socorro area soil survey and have inherently coarse spatial resolution. For specific sites where the soil survey data poorly characterize the actual soil SPLASH-DAY simulation results may be unacceptable for some purposes.

SPLASH simulates lateral flows of water across the landscape, unlike SPLASH-DAY. Lateral surface flow - overland flow - is an important water redistribution mechanism during periods of heavy rainfall. SPLASH simulations are being conducted on the nested watersheds in the Sierra Ladrones studied by Crocker. First efforts have focused on a single rainfall event in July 1991 for which precipitation was measured at the site, and for which overland channel flows have been quantified. Simulations of overland flow are sensitive to soil infiltration rate and to the surface roughness used in the calculation of flow velocities. SPLASH uses Manning's equation which predicts flow velocities as a function of water depth, slope of surface head, and surface roughness (Manning's n). Manning's n is difficult to parameterize for natural terrain. Thus, SPLASH simulations for one July event are being calibrated by adjusting Manning's n for the watershed. The derived Manning's n value will be tested in similar watersheds. If successful, SPLASH can then be used to investigate the role of lateral surface water redistribution in ecosystem functioning at the Sevilleta LTER.

## C. Vegetation Studies

*Primary Production Studies (David Lightfoot and James Gosz).*

Plant net primary production (NPP) measurements were begun in February 1999. The purpose of NPP measurements are to provide data on seasonal and annual plant productivity at each of the four core study sites; creosote bush shrubland, grassland, juniper/oak savanna, and piñon/juniper woodland. We are using the same volumetric techniques that were developed by, and are currently used at the Jornada LTER site. NPP measurements are collected from an array of permanent quadrats located in association with each of the five rodent trapping webs at each of the four sites. Data are collected for each plant species found on the quadrats. 1999 baseline standing live plant biomass data were collected in February. Standing live biomass was again measured in May 1999 to provide data on spring plant production, and biomass measurements will again be taken in September/October 1999 at the end of the growing season to provide us with summer production and overall annual production. A special project to measure NPP of juniper berries, oak acorns, and piñon nuts will be continued by Dr. Roman Zlotin at the two core sites with those species.

These data will relate to major food resources to birds and mammals, which are also being measured at those sites.

The NPP data provide us with measures of plant biomass production which we will relate to variation in precipitation over time, and across environments. The NPP data will provide us with crucial links between precipitation, plant production, and animal populations. We also will be able to assess the importance of variation in precipitation, soil moisture, and plant production across time and space.

*Nitrogen deposition and effects on NPP of grassland communities (James R. Gosz)*

Studies of nutrient deposition on the Sevilleta over time have demonstrated that there are spatial patterns of precipitation and nitrogen deposition. Convective storms in the summer monsoon season result in generally higher amounts on the eastern side of the Sevilleta associated with the Los Pinos Mountains. The chemistry of the precipitation also shows higher concentrations on the eastern side of the Sevilleta as a result of air pollution moving from north to south along the chain of mountains. This combination of higher precipitation containing a higher concentration of nitrogen results in increased nitrogen deposition rates on the east side of the refuge. These values are for wet deposition amounts; total nitrogen deposition from wet, dry and gaseous absorption are likely to be 2 to 3 times the values of wet deposition. These results lead to the question of the role of increased nitrogen levels on the dynamics of species in this biome transition zone. Some of our results demonstrate that successive years of above normal moisture can lead to nitrogen limitation on plant growth; a decreased rate of growth per unit of precipitation. We performed two nitrogen fertilization experiments in the summer of 1998 to be able to test the species specific influence of increased nitrogen deposition at levels that can be expected in this region in the next 20 years.

The first experiment was a randomized complete block design with the following treatments replicated four times (i.e., four blocks): control, 10 kg/ha N addition, 20 kg/ha N addition, 10 kg/ha N addition with legumes removed, and control with legumes removed. The individual plots were 200 $m^2$ and were measured (harvested) with a riding lawnmower. The plots were mowed in February 1998 to removed standing dead material from the previous year and remowed in September to harvest the current season's biomass production. Legumes were removed as they senesced in May and June. The randomized complete block design was established both in a black grama (*Bouteloua eropodia*) dominated grassland and a blue grama (*Bouteloua gracilis*) dominated grassland. The data are grams per $m^2$ based on 200 $m^2$ plots. Only 20 kg/ha treatments were significantly different from controls and the legume removal plots were pooled with the nonremoval plots for this analysis. While both species types showed a signficant response to 20 kg/ha nitrogen, the blue grama response was much greater than that of black grama.

A second experiment was performed using a different production measurement technique. Individual plants with a range of sizes were harvested to yield a green biomass to plant volume relationship. That relationship was used with measurements on individual plant volumes in 1 $m^2$ quadrats for each of the two species. Nitrogen was applied to a 30 m x 45 m plot at a rate of 20 kg/ha N for a black grama dominated plot and a similar sized blue grama dominated plot. Similar plots were set up as controls. In each of these plots, 1 $m^2$ quadrats were used to develop plant volumes of each species per quadrat and the biomass/volume relationship used to estimate the

biomass produced during the 1998 growing season. The results showed that only blue grama demonstrated a significant effect due to increased nitrogen availability. While the two different experiments used very different techniques for measuring production, it is clear that nitrogen can promote an effect that is species specific. Since blue grama represents a dominant species from the Great Plains biome and black grama represents a dominant species from the Chihuahuan Desert biome, the role of increased nitrogen deposition due to increasing human activity in the region may play a role in the interaction of these species in this transition zone.

*Ecotone Dynamics and Vegetation Transects (Bruce Milne, Larry Li).*

During the last year, we focused on understanding ecotonal dynamics via analysis of the long-term vegetation transect data, using conventional and newly developed methods. The data have been cleaned for cross-scale analyses of the Deep Well and Five Points sites. We have accomplished the following projects:

1. We used the Jarque-Bera test, Shapiro-Wilk test, and Kolmogrov-Smirnov test to calculate the normality of species-abundance distributions for the two sites. The results show that more than 60% of the distributions are log-normal, which is consistent with many species-abundance distributions reported in the ecological literature. Log-normal distributions are considered to indicate dynamics that are a function of multiple variables.

2. Using species relative abundance-rank distributions (dominance-diversity curves), we studied relationships among dominant, subordinate and transient (rare) species between the Deep Well and Five Points sites. Fractal dimensions and Hurst exponents of species distributions indicate increasing fluctuations, and suggest that species interactions are stronger at the grass dominated Deep Well transect, compared to Five Points. As expected, transient species are more variable than other species at both sites.

3. We used binary coefficients (Jaccard, Sorensen, simple matching coefficient, Baroni-Urbani, and Buser coefficient) and distance coefficients (Euclidean distance, average distance, Bray-Curtis measure, and Canberra metric) to study similarity in community structure between two locations and seasons for each site. These conventional indices revealed some trends of ecotonal dynamics; but further analyses are needed for understanding the relationships.

4. Using species richness, Shannon-Wiener measure (based on total vegetation cover, mean patch sizes and their variations for each species), Simpson's index and Gini index, we calculated changes in species diversity and evenness over time. We also defined a new set of diversity indices for characterizing spatio-temporal fluctuations of the two communities along spatial gradients. Results from Deep Well and Five Points are very promising. An examination of the link between NPP, species-area relationships, and cross-scale diversity are in progress.

5. We used fractal and multifractal analyses for studying scale invariance and covariance properties of the two vegetation transect data sets. Our results show that separate scaling processes govern small and large scale vegetation dynamics at both sites. For Deep Well there is a broken scale at about 0.8 meters; below this scale, vegetation change follows a simple fractal, but above the scale the system is multifractal. For Five Points the broken scale is at about 1 meter. Again below the scale is a simple fractal and above the scale it is multifractal. This is very interesting

discovery because such scale breaking suggests that complex processes underlie changes in the community patterns. We need to consider scaling separation in future, spatially-explicit, dynamic modeling. Wavelet analysis further supports large scale dynamics and scale shifts of the two sites for seasonal and annual changes.

The above combination of methods greatly improves our ability to elucidate the mechanisms of natural patterns and the biodiversity of the two Sevilleta transects. Results can be observed at: **http://sevilleta.unm.edu/data/archive/plant/**

*Vegetation change following removal of keystone mammalian herbivores: A multi-scale analysis of desert grasslands in New Mexico (Daniel Ryerson and Robert Parmenter)*

Responses of plant communities to mammalian herbivores vary widely, due to variation in plant species composition, herbivore densities and forage preferences, soils, and climate. However, synthetic generalizations from the scientific literature concerning plant community responses to herbivory over large landscapes remain enigmatic, due to many confounding and uncontrolled environmental factors operating simultaneously during different experiments in different places at different times (e.g., precipitation dynamics, varying mixes of plant species and herbivores). In this study, we evaluated simultaneous vegetation community changes in six dominant vegetation types on the 100,000 ha Sevilleta National Wildlife Refuge (SNWR) in central New Mexico, USA, over a 20-yr period following removal of the major mammalian herbivores (livestock and prairie dogs) in 1972-75. Thirty study sites were established in 1976 within and outside of the SNWR, and these sites were resampled in 1986 and 1996 using line transect methods. At the landscape scale, repeated measures ANOVA of percentage cover measurements showed no significant overall net changes in total perennial plant basal cover, either inside or outside the refuge; however, there was an overall increase in annual forbs and plant litter during 1976-96. At the community (site) scale, significant changes in species composition and dominance were observed; each community exhibited varying degrees of change, with black grama grass (*Bouteloua eriopoda*) communities being the most dynamic and burro grass (*Scleropogon brevifolius*) communities being the most persistent. At the population (individual) scale, species-specific changes were observed; snakeweed shrubs (*Gutierrezia sarothrae*) greatly decreased while black grama grass increased. The non-uniform, multi-directional changes at the population and community levels acted to prevent detection of overall changes in perennial vegetation at the landscape level. Areas outside the SNWR, that were subjected to continuous herbivory, showed community-specific responses, but some species displayed changes associated with precipitation rather than herbivory; thus, the observed responses cannot be attributed solely to removal of mammalian herbivores, and in many cases can be explained by short- and long-term fluctuations in climate regimes. These results emphasize the unique, community-specific responses of vegetation types to mammalian herbivores under otherwise similar climatic conditions, and illustrate the value of multi-scale approaches to understanding the impacts of plant-herbivore interactions.

*Plants Living on the Edge: Climate, Disturbance, and Shifts in Ecotonal Boundaries (Deb Coffin Peters)*

The overall objective of this work is to evaluate the processes and environmental factors that are important in determining patterns in coexistence and dominance for species from different

ecosystem types that meet at the Sevilleta. The overall hypothesis is that plant-level processes (recruitment, growth, and mortality) interacting with climate, disturbance, and soils result in patterns of vegetation at multiple spatial and temporal scales. The approach is to use a combination of experiments and simulation model analyses to address specific questions related to two major parts: (A) the effects of environmental factors on plant population and community dynamics, and (B) the response of dominant plant populations to environmental factors. A third part (C) includes cross-site studies.

**1. The Role of Environmental Factors in Generating and Maintaining Patterns in Vegetation.**
Both long- and short-term field studies as well as simulation models are being used to evaluate the effects of climate, small animal disturbances, and soils on plant community dynamics.
*Plant removal study (ongoing):*
In 1995, a long-term experiment was initiated to evaluate the effects of removing the dominant species only from plant communities. The objectives were two-fold: (1) to evaluate plant recovery and identify new dominant species and assemblages after the current dominant is removed and kept off the plots through time; and (2) to evaluate if dominant species with different life history traits have different legacy effects on recovery of other species through time. Within each community, the dominant species, either blue grama, black grama or creosotebush, was removed from within 5 3m x 4m plots with minimal soil disturbance. This size is comparable to kangaroo rat mounds and adjacent vegetation. Five control plots were also located at each site. In addition, five blue grama and five black grama removal plots were conducted in a mixed stand of these two species, and five black grama and five creosotebush removal plots were conducted in a mixed black grama-creosotebush stand. Plots have been maintained through time by removing new individuals of the appropriate dominant species. Cover and density by species have been estimated annually (1996, 1997, 1998) for all plots at peak standing crop (mid-September). An additional set of plots was started in March (1998) at the foothills site, an area with different climate, vegetation, and soils than McKenzie Flats.

*Vegetation and kangaroo rat mounds (REU project):*
In 1997, cover of vegetation was sampled on 10 active bannertail kangaroo rat mounds located either in patches dominated by blue grama or black grama. We hypothesized that kangaroo rat mounds may promote the growth and dominance by faster growing, stoloniferous black grama plants compared to long-lived, slow growing blue grama plants. We found that black grama cover in blue grama-dominated patches was higher around kangaroo rat mounds compared to undisturbed areas away from mounds. Similar black grama cover was found around mounds located in patches of black grama as in patches located in blue grama. By contrast, blue grama cover was lower around mounds compared to undisturbed areas. These results provide an explanation for species dominance patterns of blue grama and black grama at intermediate spatial scales. Results have been published in Fields et al. (1999).

**2. Studies of Plant Populations in Response to Environmental Factors**
Because of the importance of black grama and creosotebush in Chihuahuan desert ecosystems, and of blue grama in shortgrass steppe grasslands, the plant population studies are focusing on these three species.

*Recruitment:*
A multilayer, daily time step soil water simulation model (SOILWAT) was used to evaluate the probability of seedling establishment for black grama and blue grama. We evaluated the effects of climatic variation across multiple temporal scales (seasonal, interdecadel, and long-term directional) to the probabilities of establishment of each species at the SNWR. We found that the two species have different regeneration strategies. Blue grama has a broad pattern of establishment that occurs from May through September, and includes periods with high year-to-year variation in precipitation. By contrast, black grama has a narrow distribution of establishment events that occur primarily in July when precipitation amounts are most reliable. We also found that climatic conditions from 1949-1968 were more favorable for B. eriopoda establishment compared to the cooler, wetter period from 1969-1988 that favored B. gracilis establishment. Dr. Coffin has a manuscript submitted on this project: Coffin, D. P. Climatic variation and patterns in seedling establishment of two dominant grasses at an ecotonal boundary. Submitted to *Journal of Vegetation Science.*

A growth chamber study using blue grama seeds from the Sevilleta and SGS-LTER, and black grama seeds from the Sevilleta was recently completed to determine experimentally the relationship between soil texture, water availability, and seedling establishment. These results are in a submitted paper: Minnick, T. J., and D. P. Coffin. Soil texture and precipitation effects on the germination and growth of *Bouteloua gracilis* seedlings. Submitted to *American Journal of Botany*.

*Seed production and storage in the soil:*
In 1995 and 1996, a study of seed production of blue grama and black grama was conducted at four of the plant removal sites. Soil samples (0-5, 5-10 cm) were collected from these sites in November (1995), November (1996) and April (1997) to determine the availability of germinable seeds to these communities, and to relate seed production with seed storage to determine effectiveness of storage. We found that the key process limiting recruitment differed for the two *Bouteloua* species. High seed production, yet low viability by *B. eriopoda* was accompanied by few seeds (< 15%) stored in the soil. By contrast, *B. gracilis* produced fewer seeds with higher viability than *B. eriopoda*, and 10-25% of the seeds produced were found stored in the soil. Combining these results with the analyses (above) of seedling establishment, we found that recruitment of *B. eriopoda* is more limited by the availability of viable seeds and *B. gracilis* is more limited by seedling establishment. These results are in a submitted paper: Peters, D. P. C. Key processes limiting recruitment for two dominant grasses at a semiarid-arid grassland ecotone. Submitted to *Ecology* in 1999.

*Grass-shrub interactions:*
We are also investigating interactions between individual black grama and creosotebush plants in order to determine their influence on patterns in species diversity from small to large-scales. We recently conducted simulation analyses on the controls on seedling establishment of creosotebush. Results are being presented in: Hochstrasser, T., and D. P. Coffin Peters. 1999. The influence of dominant plants on water dynamics at a semi-arid grassland-shrubland ecotone: implications for the recruitment of *Larrea tridentata*. [Annual Meeting of the Ecological Society of America, Spokane, WA. August 7-12, 1999], and by Hochstrasser, T., and D. P. Coffin Peters. 1999. Decomposing the complexity of species coexistence patterns: an example from a semi-arid grassland-shrubland transition zone. [World Congress for Landscape Ecology, Snowmass, CO, July 30-Aug. 3, 1999].

*Synthesis using simulation modeling:*
Simulation modeling is being used to evaluate long-term effects of climate, small disturbances, and soil texture on species dominance and plant community composition. The ECOTONE individual plant-based model simulates the size and age of each plant on a small plot through time at an annual time step. ECOTONE was modified for grass-shrub transition zones at the Sevilleta from the STEPPE model developed for semiarid grasslands at the SGS-LTER. Two sets of simulations were conducted. One set evaluated the importance of initial vegetation and soil conditions and seed dispersal constraints to perennial grass response to climate change. Five patch types were simulated at the SNWR at varying distances from black grama seed sources. Seed availability was found to be most important to patches with small amounts of black grama at the start of the simulation. The second simulation was a regional analysis to determine if shifts in grass vs shrub dominance will vary depending on initial vegetation-soil conditions as well as current climatic conditions. The model was parameterized for four sites in the Chihuahuan desert (Albuquerque, SNWR-LTER, Elephant Butte, and JER-LTER). We found that sites in the north with high available water are predicted to shift from shrub to black grama-dominated as a result of climate change. Sites low in available water are predicted to shift from shrubs to other perennial grasses and forbs that are less drought-tolerant than black grama. By contrast, sites in the south are predicted to shift to other perennial grasses and forbs regardless of the initial vegetation-soil conditions. Two talks were presented:
Peters, D. P. C., and J. E. Herrick. 1999. Vegetation-soil feedbacks and sensitivity of Chihuahuan desert ecosystem boundaries to climate change. Annual Meeting of the Ecological Society of America, Spokane, WA. August 7-12, 1999.
Peters, D. P. C., and J. E. Herrick. 1999. Landscape-scale processes and sensitivity of Chihuahuan desert ecosystems to climate change. World Congress for Landscape Ecology, Snowmass, CO, July 30-Aug. 3, 1999.

*Soil and climatic control of plant growth and landscape pattern across a desert-grassland Ecotone (Charles Buxbaum and James Gosz).*

**1. Landform Geomorphology, Soil Heterogeneity, and the distribution of Blue Grama, Black Grama, and Creosote on the Llano de Manzano Landform.** This study constitutes an examination of the soil underlying the mosaic of plant communities dominated by either blue grama (*Bouteloua gracilis*), black grama (*Bouteloua eriopoda*), or creosote bush (*Larrea tridentata*) on a virtually flat (less than 0.5% grade) section of the Llano de Manzano Landform known as the McKenzie Flats. Nine soil pits were dug in sites dominated by one of three species or sites transitional from blue to black grama, or black grama to creosote. These local transitions, on a regional scale, represent the shift from shortgrass prairie to desert grassland to desert shrubland.

Soils were characterized in each of these nine sites for variables such as texture, development and thickness of an argillic (clay-rich) horizon, depth to Holocene calcium deposition, and depth to Pleistocene petrocalcic (caliche) layers. Multivariate tests of the data show that depth to neogenic (Holocene) calcium carbonate deposition, thickness and development of the clay rich horizon, and depth of the entire soil profile are highly variable on this seemingly homogeneous land surface; and

that the distribution of plant communities in this ecotonal zone reflects the pattern of soil heterogeneity.

The soil heterogeneity is due to the fact the current aeolian-deposited Holocene soil overlies a Pleistocene surface that was dissected by numerous streams running from the Los Pinos Mountains to the Rio Grande when the climate was much more mesic than present. The soil over the buried paleostreams is deeper and has had longer time to develop than the shallower interstream soils. Due to uplift in two areas (Black Butte and Five-Points) the ancient petrocalcic horizon is exposed at the surface. These areas are dominated by creosote. Black grama dominates the shallow soils that have buried the interchannels; and blue grama (the least xeric species) dominates the soils that overly the buried channels, with transitional communites in between. The differences in soil development clearly govern differences in microclimate that are great enough, at the ecotone, to regulate plant species distributions. This study, furthermore, shows that small spatial scale phenomena may be influenced by very large temporal scale phenomena. In this case the spatial scale is only 100 to 300 meter patches, while the temporal scale between deposits of the current soil and the buried soil is 500,000 to 1,000,000 years. This study is complete and is being revised for publication.

**2. Desert and Prairie Grassland Species Responses to Changes in Moisture Regime at the Chihuahuan Desert-Shorgrass Prairie Ecotone.** In this moisture manipulation study, responses of blue grama and black grama to seasonal (i.e. winter and summer) and all-year precipitation exclusion were compared with plants treated with precipitation doubling. These, in turn, were compared with untreated controls. The treatments were maintained for two full years. Plant cover was measured in 1995 (pre-treatment), 1996, 1997 (end of treatment), and again in 1999 (after two years of recovery from either rain exclusion or rain doubling). In addition to percent cover, above-ground biomass (estimated using allometric equations) was examined. Repeated measures analyses of the results of this experiment are presently being interpreted, but there are notable treatment effects as well as significant species differences. The curves generated by this study may be useful predictors of rates of species change in the event of periodic drought or increased moisture regime. The study should be complete by the summer of 2000.

## D. Nutrient Cycling and Soil Ecology.

*Decomposition Studies (Carl White and John Craig)*

For 1998-99, our efforts were maintained with some alteration on our long-term projects. Primary inputs to ecosystems are determined from chemical analyses of bulk precipitation and the wet/dry collectors (see meteorological section). Replicate litter bags of last year's production of black grama, juniper, Indian rice grass, and creosote were placed at 4 sites, two sites (one in grassland and one in pinyon-juniper) that have had decomposition studies since 1990 and two new sites increosote and juniper savannah areas. The past sites at Rio Salado and Red Tank were not continued in an effort to consolidate the research effort and lengthen the vegetation gradient on the east side of the Refuge. Collections are made seasonally through the first year and after two years. A fifth species, blue grama, is placed at the Deep Well site (grassland), which represents the most extensive mixture of blue and black grama. The Deep Well site also has the LIDET inter-site

decomposition study. The decomposition study has been completed on the Sevilleta web site and current efforts are underway to complete N and C analyses on the beginning and one year samples.

*Nitrogen Dynamics (Carl White, John Craig, and James Gosz)*

Soil N availability and potentially mineralizable N has been measured in the east-side grasslands over nearly a ten year period. This study began as part of a study on controls of net primary production in the grassland with soil N considered a limiting factor during periods of greater-than-average precipitation. This study has been completed and is available on the web site. A manuscript has been started detailing the results of experiments on the effects of moisture and temperature on N mineralization potentials. Both factors have non-linear effects on N mineralization, which is best fit by hyperbolic functions.

In addition to these studies, fertilization experiments have been conducted as described above in the Vegetation Section.

*Soil Erosion Studies (Carl White and John Craig)*

Soil erosion bridges were maintained at the four core sites. The soil surface is very dynamic in some locations, with changes of 3 cm common. Associated with the bridge measurements are data on soil texture, water holding capacity, organic matter, N mineralization potentials, total N and P, and soil conductivity. Coupled with the net gain or loss of the soil surface, changes in nutrient resources can be calculated.

Information about all nutrient cycling studies at the Sevilleta are available on the web at:
**http://sevilleta.unm.edu/research/local/nutrient/**

*Plant Regulation of soil nutrient distribution in the northern Chihuahuan Desert (Anne Cross and William Schlesinger).*

Vegetation throughout the southwestern United States has changed from perennial grassland to woody shrubland over the past century. Previous studies on the development of "islands of fertility" focused primarily on only the most limiting, plant-essential element, soil nitrogen (N). The research, conducted between 1989 and 1994, addressed the question of whether other plant-essential elements, namely phosphorus (P) and potassium (K), showed similar concentration gradients under the desert shrub *Larrea tridentata*, creosote bush. It also examined whether the spatial distribution of N, P, and K differed from that of essential, but non-limiting nutrients, namely calcium (Ca), magnesium (Mg), and sulfur, (S) and non-essential elements, namely sodium (Na), chloride (Cl), and fluoride (F). Within adjacent grassland and shrubland plots, surface soils were collected under and between vegetation and analyzed for a suite of soil nutrients. Soil nutrient distribution followed a uniform pattern that mirrored the spatial homogeneity of bunchgrasses in the grassland, but followed a patchy distribution that mirrored the spatial heterogeneity of individual shrubs in the shrubland. The main differences were that in the grassland, all elements were uniformly distributed, but in the shrubland the plant-essential elements, nitrogen, phosphorus, and potassium, were concentrated under the shrub canopy, and the non-limiting and non-essential elements were either concentrated in the intershrub spaces or were equally concentrated under

shrubs and in the interspaces. Our results show how vegetation shifts from grassland to shrubland contribute to long-term, widespread change in the structure and function of desert ecosystems.

We tested the hypotheses that 1) biological processes regulate the distribution and availability of limiting plant nutrients (e.g. N, phosphorus (P), and potassium (K)), in soils; therefore, the greatest concentrations of N, P, and K should be under vegetation and the spatial distribution of these elements should mirror the spatial arrangement of vegetation in grassland and shrubland sites; 2) geochemical processes regulate the abundant, but non-essential elements (e.g. sodium (Na), chloride (Cl), and fluoride (F) in desert soils; therefore, the greatest concentrations of these elements should be in the interspaces between vegetation; and 3) both biological and geochemical processes regulate essential, but non-limiting elements (e.g. calcium (Ca), magnesium (Mg), and sulfur (S)); therefore, the concentration of these elements will be equivalent under vegetation and in the interspaces. Our study determines whether the present-day spatial distribution of soil nutrients reflects prior shifts in vegetation that are associated with desertification in the southwestern United States.

At the Sevilleta NWR, grassland sites showed greater plant cover, plant biomass, and a more uniform distribution of vegetation per unit area, than the shrubland sites. Where *L. tridentata* shrubs dominate the landscape, a reduction in vegetation cover and plant biomass creates a heterogeneous, or spatially patchy, distribution. These data support the hypothesis posited by Schlesinger et al. (1990) that increases in the spatial heterogeneity of vegetation accompany desertification in the Chihuahuan Desert. Contagion analyses, which are similar to Simpson's Index with an additional term to estimate the spatial component, show a homogeneous, or spatially uniform, distribution of individual bunchgrasses that contrasts with spatially heterogeneous vegetation cover in the *L. tridentata* shrubland. Plant-essential (N, P, and K), non-limiting (Ca, Mg, and SO4-S) and non-essential (F, Cl, and Na) elements were found to be equally distributed under and between vegetation in the grassland.

The shrubland differs markedly from the grassland in its spatial distribution of vegetation and soil nutrients. As shrubland vegetation is more spatially patchy than grassland vegetation, we expected to find an increase in particulate deposition under the shrubs compared to bare ground areas between shrubs. Abiological and geochemical forces appear to regulate the cycling under and between shrubs, or more highly concentrated in the inter-shrub spaces. Vegetation appears to maintain a tight control over the cycles of biologically limiting nutrients - N, P, and K - we found them to be more highly concentrated under shrubs. Studies showing greater microbial biomass and activity under shrubs suggest that microbes capitalize on the greater carbon and moisture stores under shrubs. Typically the non-essential and non-limiting elements are deposited under shrubs through wind and water transport. Plant-essential elements, once acquired from the soil solution through root uptake, remain under the plant through recycling via litterfall, microbial litter decomposition, and microbial immobilization.

*Biological and geochemical controls on soil phosphorus availability in semiarid soils (Anne Cross and William Schlesinger).*

This study examined the concentration of organic and inorganic phosphorus in surface soils of a *Bouteloua gracilis-Bouteloua eriopoda* grassland, and a *Larrea tridentata* shrubland, in the

northern Chihuahuan Desert, New Mexico, USA. In this desert, the grassland vegetation creates a uniform spatial distribution, and individual shrubs create a patchy spatial distribution across the landscape. Most soil inorganic P is found in the HCl- and cHCl-extractable forms in grassland and shrubland soils, indicating $CaCO_3$ control over phosphorus availability in these soils. In contrast, most soil organic P is bound to Al and Fe minerals. Labile, plant-available P fractions sum to 9.5% of total P in the grassland and 6.1% in the shrubland. Organic P totals less than 15% of the total phosphorus pool in soils at the Sevilleta, comprising 13.4% in the grassland and 12.2% in the shrubland. The organic P pool may represent an important, yet often overlooked, source of P in semiarid ecosystems.

Organic P ($P_o$) contributes to P availability by controlling the labile inorganic P pool, which is important to net primary production in many ecosystems. In addition, organic P fractions may be important pools of biologically available P in grasslands, because $P_o$ is more mobile than inorganic P, which is readily fixed by mineral surfaces. The purpose of our research was to examine the nature of the labile phosphorus fractions and to quantify the organic phosphorus content of soils in a semiarid ecosystem. We tested two hypotheses. First, we expected that concentrations of labile and organic P would be greatest in grassland soils, and localized under individual plants in the shrubland. And, second, we expected that other soil attributes - texture and the concentrations of various soil elements (C, N, Ca, Mg, K, Na, S, and Cl) - would affect levels of organic P in the surface soils.

The percentages of phosphorus that reside in the inorganic fractions in the Sevilleta soils are similar to those in other Mollisols and Aridisols. Surface soils contain small pools of labile P (resin- and bicarbonate-extractable) and non-occluded P (NaOH-extractable), and large pools of occluded and carbonate-bound P (cHCl- and HCl- extractable and residual). In both vegetation types, the largest pool of P is the $CaCO_3$-bound, acid-extractable P. This fraction reflects the geochemical influence on P cycling that is dominated by high concentrations of calcium carbonate minerals in the surface soils. Comparisons of P pools in the grassland and shrubland, show greater concentrations of NaOH-extractable forms in the grassland, and higher levels of the acid-extractable forms in the shrubland. This largely reflects the abundance of Al- and Fe-rich minerals in the argillic horizon of the grassland, and the abundance of calcite in the surface soils of the shrubland.

Overall, desert soils of the Sevilleta have extremely low contents of organic phosphorus. In other Mollisols and Aridisols, bicarbonate-extractable $P_o$ concentrations average 2.9% of total P, but this fraction accounts for 0.7% of total P in grassland soils at the Sevilleta and 1.0% of total P in the shrubland. Bicarbonate-extractable $P_o$ represents phosphorus that is held in the soil by adsorption to soil particles or soil organic matter. A more striking difference is seen in the NaOH-extractable fraction, which averages 15.4% of total P in many soils, whereas in Sevilleta soils this fraction is 2.0% of total P in the grassland and 1.2% in the shrubland. NaOH-extractable $P_o$ is bound to Al or Fe minerals. It is found in the surface horizons of the grassland, and is likely transported by wind to the shrubland where it accumulates under individual shrubs. The cHCl-extractable organic P averages 10% of total P at the Sevilleta, but can comprise up to nearly 50% in other similar soils. The $P_o$ extracted with cHCl is thought to be tightly bound to Fe and Al minerals, and perhaps is unavailable to plants. Traditionally the Hedley fractionation has not analyzed the 1M HCl extract for $P_o$. Future work should evaluate this fraction to determine whether $P_o$ is bound to $CaCO_3$ minerals in arid soils.

## E. Animal Studies.

*Vertebrates Studies (Robert Parmenter, Terry Yates, James Brown, Michael Friggens, and David Lightfoot).*

Small mammal population studies continue for the eleventh year on the Sevilleta. This research measures mammal densities and population parameters at four localities representing the major biomes studied on the SWNR. There are some changes in this study from previous years; the changes are concurrent with restructuring and consolidation of field study sites and programs. The Parasite Study and the collection of voucher specimens from designated localities ended in 1998 with a decade of data. The results of this work are currently being summarized for publication (see below). The results of a decade of rodent population changes at six localities on the SNWR are also being analyzed. We reduced the number of sites from six to four this year, which allowed us to focus field technician time on the collection of NPP data as well as the establishment and monitoring of the new juniper-oak savanna site.

While last year we saw a marked increase in rodent densities at all of our sites due to El Niño precipitation and vegetation growth following a two year drought, this year's preliminary data showed a decrease likely due extremely low La Niña precipitation conditions during the past winter and spring. A recent analysis of rodent populations, vegetation growth, and precipitation amounts (Ernest et al., *Oikos*, in press) identified significant relationships in moisture and subsequent vegetation (food resources) as driving variables in small mammal population dynamics at all the Sevilleta ecosystems. Comparisons with the Sevilleta data and those of Jim Brown's long-term site at Portal, AZ, showed less concordance, indicating substantial regional differences in climatic controls on community processes.

The collaboration of the Sevilleta LTER and the CDC's long-term hantavirus studies at the Sevilleta NWR continues. Data from the Sevilleta contributed to the prediction in early 1998 of an El Niño-related hantavirus outbreak, due to predicted increases in *Peromyscus* densities. The increases actually occurred as predicted in 1998-99, and the public health warnings were issued to prevent hantavirus infections in people. While the Southwest has experienced an increase in human cases of hantavirus, the increase is less than what was predicted, and thus the public health warning may have had a positive effect. We are currently collaborating with a graduate student (Ms. Marjorie Hudson) in UNM's Sociology Department to evaluate the effectiveness of health warnings of hantavirus risk (based on our Sevilleta/CDC data) to change the cleaning habits of residents in New Mexico and the Four Corners area.

Finally, we have been collaborating with Dr. Lucina Hernandez, Director of the Mapimi Field Station, Instituto del Ecologia, Durango, Mexico, on a synthesis study of ecological factors influencing diet selection of coyotes on the Sevilleta. We have combined a number of data sets, including precipitation, NDVI from Sevilleta AVHRR coverages, percentage plant cover from ground measurements, and densities of antelope, rabbits, rodents, birds, and arthropods, to address several hypotheses on the coyote's prey selectivity, reproductive success, spatial distributions, and seasonal dietary dynamics. Initial results are being presented by Dr. Hernandez at the 1999 ESA meeting in Spokane.

Additional ongoing mammal studies include population density estimates of rabbits, coyotes, antelope and birds. Data on vertebrates are at: **http://sevilleta.unm.edu/data/archive/animal/**

*Parasites in rodent populations (Don Duszynski, Kimberly Decker).*

Between 1989 and 1998, over 3,000 rodents from *Dipodomys* species and *Perognathus* species were collected and identified from the four major core field sites. All collected animals were killed and examined for endo-parasites (acanthocephala, nematodes, cestodes and coccidia). This research focuses on three endoparasite groups: Coccidia, nematodes and cestodes. Specific analyses address 1) how prevalence of each parasite in each host species may differ due to host age, sex, reproductive status, mass, density, parasite-parasite interactions and /or host specificity; and 2) how this prevalence changes due to abiotic factors such as habitat, season, or precipitation. A logistic regression was used to determine which host characters and which abiotic factors (if any) indicate a parasite infection. The most prevalent parasites over the ten years were *Pterygodermatites dipodomis* (42%), *Eimeria chobotari* (35%), *Mastophorus dipodomis* (19%) and *Heteromyoxyuris deserti* (16%). Over the ten years, 49% of the hosts were infected with one or more parasites. *Dipodomys spectabilis* was the most infected host population (80%), followed by *D. merriami* (71%), *D. ordii* (55%), *Perognathus flavus* (16%) and *P. flavescens* (15%) . The most significant variables predicting parasite prevalences for specific parasites include habitat/site, season, winter precipitation and host species. However, no parasite prevalences were correlated with any other, indicating that each parasite species varied independently and that no generalizations about predictor variables can be drawn. Overall, the parasite prevalences in these rodents at the SNWR vary in independent and complex ways.

*Arthropods (David Lightfoot, Robert Parmenter).*

We are monitoring select groups of ground-dwelling arthropods at each of our four core-study sites to determine how variation in seasonal and annual precipitation and plant production influence populations of predator and detritivore arthropods. These data will allow us to relate variation in precipitation, plant production, arthropods, and rodents. Additionally, we are comparing the stability/resilience of ground-dwelling arthropod assemblages across the four different vegetation zones and among different arthropod trophic groups. Since 1998 we have focused our sampling on the four core sites only. The Sevilleta ground-dwelling arthropod study is also part of a cross-site study which includes the same sampling protocols at the Jornada LTER, and Bandelier National Monument in northern New Mexico. This array of sites allows us to examine the effects of El Niño/La Niña events on plants and arthropods across the transition from the northern Chihuahuan Desert to the Rocky Mountains, incorporating local variation due to elevation and edaphic differences.

We have continued to collect and process pitfall trap samples over the past year. All samples through December 1998 have been sorted, tabulated, and the data entered into our long-term database. We are currently collecting and processing the 1999 samples and analyzing the long-term data. Data can be found at: **http://sevilleta.unm.edu/data/archive/animal/arthropod/**

In addition to the surface-active arthropods being collected via pitfall traps, we are now sampling foliage-dwelling species of arthropods at our main core field sites (Chihuahuan Desert, Short-Grass Steppe, Juniper-Oak Savanna, and Piñon-Juniper Woodland. These studies are part of the collaboration with our REU program, which is investigating the relationships between NPP and biodiversity in the various Sevilleta ecosystems.

*Small Mammal Exclosure Study (David Lightfoot)*

The Chihuahuan Desert Small Mammal Exclosure Study was initiated in 1995 to determine the effects of, and feed-backs among rodents and rabbits, and other animals, plants, and soils in Chihuahuan Desert grassland and creosotebush (*Larrea tridentata*) shrubland communities. This is a cross-site LTER project, with identical experimental designs and sampling protocols at the Sevilleta and Jornada LTER sites, and at the Mapimi Biosphere Reserve, Mexico. Findings from this study will allow us to determine how small mammals influence the species composition and structure of plant communities. We also will be able to assess interactions between important consumer animal groups including rodents, rabbits, termites, grasshoppers, and ants. We will relate variation in seasonal and annual precipitation to variation in rodent and rabbit populations, and to their effects on plants and other animals. The cross-site aspect of the study provides us with an ideal comparison of locations across a latitudinal gradient across the entire Chihuahuan Desert. The intensity and effects of El Niño/La Niña events vary across this latitudinal gradient, allowing us to assess the regional impacts of these climatic fluctuations on Chihuhuan Desert biotic communities.

We have continued field measurements on vegetation, soil surface disturbance, ants, grasshoppers, and termites during autumn 1998 and spring 1999. We are utilizing data from the Sevilleta rodent trapping webs and the rabbit road surveys to provide measures of rodent and rabbit population densities, and climate data from nearby meteorological stations to provide precipitation and temperature data.

## F. Disturbance Studies

*The human history of the Sevilleta LTER research region, and implications for modern vegetation communities (Joslyn Garcia, James Gosz, Robert Parmenter).*

To comprehend the whole picture of an ecosystem, it is vital to understand the role of prehistoric people. The presence of exotic plant species usually are a result of human impact within the last several centuries. Humans were and still are major dispersal agents of exotic species. Currently, an assessment of the human carrying capacity of the Sevilleta NWR is being determined through modeling of the current vegetation and the pre/historic vegetation potential. The goal is to understand how quickly humans (Native Americans and Spanish colonists) changed their land use in response to the changing environments. Some human activities enhanced productivity while others depleted it. Human caused changes in the landscape such as wood extraction, irrigation, input of pastures, burning and livestock were key because they changed the net carbon, water, energy and gas exchange of that ecosystem. Land use altered the plant communities of the landscape by removing the indigenous species and increasing exotic species, and these exotic species changed the nutrients and water pathways of the whole system. The flora of the Sevilleta reflects the subsistence diet of prehistoric inhabitants.

Through the use of the Sevilleta GIS, we determined the vegetation classification at each archaeological site on the Sevilleta. Information from the state archaeological records was used to plot and map each site, and these were overlaid with the current Sevilleta vegetation map. It was determined which species were present at the archaeological sites. The two most dominant classes were of the Great Basin shrublands (dominated by *Atriplex canesence*) and the Rio Grande woodlands (dominated by *Populus deltoides* and *Tamarix ramossissima*). The inhabitance of the sites on the Sevilleta have been determined to be Anasazi, Mogollon, Pueblo, Hispanic, and Anglo, though some are still of unknown origin. Salt cedar and fourwing saltbush are the current dominant species at half of the archaeological sites, demonstrating recent human disturbance and exotic plant invasion. Future studies in 1999 and 2000 will provide more detailed data on the composition of pre-historical plant communities and historical sequences of plant invasions onto the Sevilleta NWR.

*Wildfires (Robert Parmenter, James Gosz, David Lightfoot, Debra CoffinPeters).*

As part of previous LTER fire studies using controlled experimental burns, post-fire measurements of vegetation re-growth have been analyzed for experimental and natural fire sites on the Sevilleta. Results to date show differences in survivorship and species-specific regrowth rates. These have been determined for all common species of perennial plants in the Sevilleta grasslands (Parmenter et al., in preparation). Animal responses to fires are negligible, with most species avoiding the fire and surviving normally in the post-fire environment. One paper has been published showing the details of harvester ant foraging behavior after the fires (Zimmer and Parmenter 1998); eight more manuscripts on plants, rodents (2), pronghorn, beetles, grasshoppers, spiders, and homopterans are in preparation.

Previous studies of natural, lightning-caused fires on the grassland area of McKensie Flats demonstrated that black grama patch size was reduced by the fire for at least 5 years after the burn. Line intercept studies of burned and unburned areas were performed in 1995 on two areas that had natural fires in 1990 and 1991. The following figure shows that the patch size distributions for black grama measured in 1995 were significantly different between burned and unburned areas (Harris and Gosz, unpubl). Patch size reflects the sizes of individual plants and distances between plants. Decreased patch size of black grama is accompanied by increased areas of exposed soil. This has significance in a number of the habitat characteristics for the burned area; e.g., surface reflectance properties, soil loss, surface redistribution of precipitation. Patch size distributions of blue grama were not significant between these burned and unburned areas in 1995 inferring that they recovered rapidly or were not influenced markedly by fire.

A lightning-caused fire occurred in June 1995 providing another opportunity to quantify effects on patch dynamics of blue and black grama. Four, 100 m permanent transects were placed along one edge of the burn with each transect having 50 m inside and 50 m outside of the burn. The following analyses were made in August 1995 and August 1998 to evaluate changes in patch sizes of blue grama, black grama, and exposed soil.

Patch sizes of black grama generally increased from 1995 to 1998 as well as a filling in (increased number of patches) reflecting the increased cover of black grama following the burn. The data

represent the total of frequencies for the 4 transects (i.e., 200 m burn transect, 200 m unburned transect). The 1996 and 1997 growing seasons were above average in moisture and plant growth that resulted in a general increase in percent plant cover for the region. However, comparison of the burn data with the unburned data shows that patch sizes for the burned area still have not recovered to the status of the unburned area. Blue grama cover also increased during the same interval; however, there was little difference between burn and unburned areas over time reflecting the reduced influence that fire has on this species.

The pattern of patch sizes of the vegetation also was reflected in the patterns of exposed soil. The distribution of soil patch sizes changed from larger patches of exposed soil in 1995 (e.g., 2 m) to an increase in the number of small patches of exposed soil in 1998. Increased plant growth generally was responsible as well as the influence of blue grama that recovered in the three years following the fire. The dominance of either blue or black grama in this biome transition zone can play a major role in the properties of the habitat after fire. It is not known if fire will control the dominance of either of these species since studies have only been made following single fires. The frequency of fires for an area may be the most important factor since there are significant differences in the rate of recovery of the two species.

*Prairie dog studies (Ana Davidson, David Lightfoot, James Gosz, Robert Parmenter).*

We have initiated a new project this year to assess the effects of Gunnison's prairie dogs on Sevilleta grassland communities. In particular, we are interested in how prairie dogs alter plant composition and vegetation structure as a result of soil disturbance and herbivory. Additionally, prairie dogs probably influence other animal species as a result of habitat alteration and competition for food resources.

Gunnison's prairie dogs were once abundant on the Sevilleta grasslands, and were undoubtedly important components of the grassland ecosystems. These animals were eliminated through poisoning efforts from the early 1900s, and continued as late as the 1970s. The extirpation of prairie dogs coincided with over-grazing and desertification of the grasslands by domestic livestock. Since the establishment of the Sevilleta National Wildlife Refuge in 1972, livestock grazing has been eliminated on the Sevilleta, and the grasslands have recovered. However, prairie dogs are still absent from Sevilleta grassland ecosystems. Recently, we have re-established a colony of Gunnison's prairie dogs near the south boundary of the Sevilleta (Davidson et al., in press), and another colony has moved onto the Sevilleta across the north boundary. This project is designed to monitor the expansion of that colony onto the Sevilleta grasslands, and to determine how those prairie dogs interact with other animals and plants as this expected expansion occurs.

Banner-tailed kangaroo rats are currently the dominant rodents that disturb soils and modify vegetation. We have observed the prairie dogs occupying and perhaps replacing the banner-tail kangaroo rats as they colonize the grassland. A principal goal of this project is to determine how these two keystone species interact with each other, and other animals and plants. Ultimately, we hope to determine whether or not prairie dogs are significant keystone species in these grasslands, modifying soils, vegetation, and animal communities.

To date, we have determined the extent of this colony, and we are now mapping the colony by use of low-level aerial photographs and GPS coordinates. We will begin vegetation measurements and monitoring of other rodents, lizards, and arthropods later this summer. Measurements will focus on soil disturbance gradients surrounding prairie dog and banner-tailed kangaroo rat mounds, and landscape/plot analyses of vegetation patterns. This will be a long-term study designed to follow expansion of the colony over time, documenting vegetation and animal community changes as colonization of the grasslands occurs.

*Riparian Flooding and AET (Cliff Dahm, James Cleverly, Manuel Molles, Cliff Crawford, Maury Valett, Padinare Unnikrishna, Terri Mulhern).*

Eight sites were established along the riparian gallery forest of the Rio Grande during the summer and fall of 1998 to study evapotranspiration from these ecosystems. Sites include areas dominated by native cottonwoods and exotic saltcedars. Four sites are in areas that receive regular flooding and four sites are in areas decoupled from the river. The project is funded through a NASA ecosystem restoration program, and one site in an unflooded saltcedar stand is located at the Sevilleta. Evapotranspiration from the sites will be measured with ground water mass balance, modified Penman Monteith, Bowen ratio, 3-D sonic anemometry, and satellite remote sensing. The objectives of the project are to 1) determine annual evapotranspiration rates for native and non-native riparian plant communities using multiple techniques, 2) assess the effect of regular flooding relative to long inter-flood intervals on annual evapotranspiration rates, 3) compare remote sensing, water balance, and micrometeorological techniques for estimating evapotranspiration, and 4) scale up plot measurements of ET to provide an annual reach estimate of riparian ecosystem water use. Field measurements to accomplish these goals are currently underway.

## G. Data Management

The Sevilleta LTER program took advantage of an NSF special supplement opportunity to upgrade network connections to the Sevilleta Field Research Station which serves as the focus for our research. The WAN equipment and connection between UNM and the field station is in the process of being upgraded, and will bring that connection up to full T-1 speed (1.54 Mb/s) with a T-3 (45 Mb/s) capability. The LAN backbone and connections have been upgraded to 100 Mb/s to the desktop and 384 Mb/s between buildings - these connections allow Sevilleta researchers to take full advantage of the new capability. Part of the upgrade process that will be complete this year is the repositioning of the termination point of the connection to the router that is connected to the vBNS connection at UNM. This upgrade will also allow the Sevilleta Schoolyard LTER Program (see below) to take full advantage of vBNS access and the data services at Sevilleta. The Sevilleta LTER homepage continues to be expanded through the efforts of Richard Mott. Additional databases and metadata have been coming on line, making more of the Sevilleta's data available to the general public. Sevilleta web page use by the public continues to be exceedingly high.

The Sevilleta LTER Program lost its data manager, Gregg MacKeigan for family reasons in May. James Brunt, LTER Network Office Associate Director and former Sevilleta data manager, has stepped in on available time to direct the Sevilleta's data management group until the position is refilled.

## H. GIS/Remote Sensing.

The major goals of the remote sensing studies continue to be (1) the refinement of the Sevilleta Vegetation Map (GIS data layer) that will form the basis for the landscape modeling simulations (hydrology and NPP), and (2) the development of additional GIS data layers of the Sevilleta at various scales derived from a number of remote-sensing platforms.

*Development of the Sevilleta Vegetation Map (Esteban Muldavin, Greg Shore, Kimberly Taugher, Bruce Milne).*

The Sevilleta National Wildlife Refuge in central New Mexico is an important site for the maintenance of biodiversity in the Southwest, and a center for the study of the effects of global change on aridland ecosystems. To support management of these important biological resources, and effective design and implementation of scientific research, a vegetation classification and 1:70,000 scale map of actual vegetation was developed (Version 1.0). The map is based on an unsupervised classification of multi-temporal LANDSAT Thematic Mapper (TM) satellite imagery using a Normalized Difference Vegetation Index (NDVI) computed from 12 TM images that variously cover the April-to-October growing seasons from 1987 to 1993. Thirty-two spectral classes were derived from unsupervised classification and grouped into 13 map units based on similar vegetation composition and spatial relationships. A preliminary vegetation classification following the US National Vegetation Classification system was developed from extensive ground survey work (251 plots), and serves as a basis for defining map units. Eighty-seven plant associations were recognized among 27 Cover Types (Alliances). The targets for the mapping effort were 15 major Cover Types: Black Grama, Blue Grama, Galleta Grass, Indian Ricegrass, Alkali Sacaton, Giant Sacaton, Fourwing Saltbush, Broom Dalea, Creosotebush, Honey Mesquite, Oneseed Juniper, Pinyon Pine, Salt Cedar, and Rio Grande Cottonwood. Map units can reflect single cover types, or transitions that combine two or more. An annotated map legend provides details on species composition and structure along with known major inclusions of other types. This is the highest resolution and most accurate map yet developed for the Sevilleta, and is appropriate for use at 1:50,000 or greater scales. To meet future needs for even higher resolution maps in management and research, new approaches will be needed that take advantage of new technologies. For example, a technique is suggested that builds directly upon this map to increase accuracy and precision in a cost-effective manner by combining the TM imagery with aerial photography or high-resolution sensor data (the next generation -- Version 2.0). The Sevilleta Vegetation Map (Version 1.0) and this report will be made available in digital form on the web page of the Sevilleta Long Term Research Program at the University of New Mexico

*Shrub demography study (Joyce Francis, Jim Gosz).*

We are examining creosote and yucca distributions since 1989 using high resolution, remotely sensed data. The data includes aerial photography of McKenzie Flats collected in 1989 and 1993. These photographs have been digitized at approximately a 20 cm resolution. They will be compared to 5500 ADAR (1 m resolution) imagery collected in 1998. Preliminary examination of the imagery suggests that both creosote and yucca have increased in cover value since 1989. Increased creosote cover appears to be due to growth of existing individuals rather than establishment of new plants. Yucca appears to be increasing in cover due to growth of individuals as well as an increase in plant density.

*Grazing exclusion project (Nancy Golubiewski, Carol Wessman).*

This is a collaborative project with the University of Colorado evaluating vegetation response to grazing. We are using multi-sensor and multi-resolution remotely sensed data to compare ungrazed plots to grazed plots outside the refuge boundary and to plots within the boundary. This approach allows us to evaluate the usefulness of different sensors and data resolutions for detecting change in semiarid grasslands while simultaneously investigating the structural and functional changes associated with recovery from grazing.

## I. Cross-site Activities.

*Chihuahuan Desert small mammal exclosure study with Jornada LTER and Mapimi, Mexico (David Lightfoot and James Brown).*

We continue to make routine measurements on the small mammal exclosure study plots at the Sevilleta. Vegetation quadrat measurements, including plant canopy cover, plant species composition, and soil surface disturbance were measured on all quadrats in the autumn of 1997, and early summer of 1998. Grasshopper species composition and abundance, ant nests, and termite foraging activity were measured on all plots at the same time. All data have been entered into computer database files. Image processing analysis of aerial photographs of all study plots is complete for the Sevilleta and Jornada. We continue to have excellent collaboration and interaction with researchers from the Jornada and Mapimi. We are planning a workshop at the Mapimi Biosphere Reserve, Mexico, to compare the results of our research at the Sevilleta, Jornada, and Mapimi, over the past four years, and to plan future collaborative cross-site research. Four students have completed research projects that were funded by our NSF LTER cross-site grant. One masters level student completed a project on rodent consumption rates, three REU students completed projects, including one on seed harvesting ant nest locations relative to soils and vegetation, one on microhabitat effects of rodent foraging, and one on aerial photograph interpretation of vegetation and soil patterns. We are currently preparing publication manuscripts to for all of these projects. One Ph.D. level student is currently conducting field research at Sevilleta, Jornada, and Mapimi for a study of diversity patterns of succulent plants.

*Ground-dwelling Arthropods: Bandelier/Sevilleta/Jornada (David Lightfoot).*

We have implemented the same sampling design and protocols for monitoring ground-dwelling arthropods at the Jornada LTER site (NSF funding to the Jornada LTER program) in southern New Mexico, and at Bandelier National Monument (USGS-BRD funding) in northern New Mexico. This extends the Sevilleta ground-dwelling arthropod studies to a regional level, encompassing an environmental gradient from the southern Rocky Mountains to the northern Chihuahuan Desert. All three study areas include a variety of major habitat types, and elevation gradients. We are coordinating sampling times, target arthropod groups, and data formatting at all three sites. We will continue these efforts through 1999. We have acquired additional funds from DOE to add another site in the Jemez Mountains near Bandelier, to focus on the effects of El Nino events on arthropods across an elevation gradient.

*Fire Ecology: Comparisons of vegetation responses to fires among desert grasslands sites in New Mexico (Deb Coffin Peters, David Lightfoot).*

We are conducting cross-site studies of the role of fire in Chihuahuan desert ecosystems. We conducted a multi-scale sampling of blue and black grama patches at the SNWR in July 1999. Our hypothesis was that different patch types would respond differently to fire. We also sampled unburned patches within the larger, burned matrix and expected that these patches would be areas of nutrient and soil accumulation through time that would positively affect the vegetation response. A similar sampling scheme was used before and after a controlled burn of 1000 acres at the Jornada Experimental Range in June 1999. At the JER-LTER, we focused on the response of black grama and honey mesquite after fire.

*Cross-site activities of plant populations and communities (Debra Coffin Peters).*

Many of the plant population and small disturbance studies have comparable studies at the SGS LTER. For example, the seed production and storage studies of blue grama and black grama conducted in 1996 at the Sevilleta have similar methods and analyses as a seed production study in place since 1989 at the SGS and a seed storage study conducted in 1985-86. The plant removal plots started in 1995 at the Sevilleta are similar to small-scale disturbance plots at the SGS. We are also conducting cross-site simulation analyses using both the SOILWAT and ECOTONE models. A number of our studies have also been conducted at the JER LTER site, and we expect that an increasing number of SEV-JER studies will be initiated in the near future.

*Cross-site energy balance study (Al Rango, Jerry Ritchie, Tom Schmugge, Carol Wessman,).*

The USDA Agricultural Research Service is collaborating with the Jornada, Sevilleta and Shortgrass Steppe LTER's to compare semi-arid grassland dynamics across these site. Specifically, they are using ground, aircraft and satellite remote sensing platforms for the multi-scale detection of landscape patterns. Data from different sensors will be used to quantify the hydrologic budget and investigate vegetation response to changes in water and energy balances across sites.

*US-Hungarian cross-site research (Debra Coffin Peters and James Gosz).*

As part of our US-Hungary project (Coffin and Gosz; INT95-13261), we are conducting cross-site comparisons of vegetation pattern and dynamics at three LTER sites (Sevilleta, SGS, JER) and three dry grassland sites in Hungary. Hungarian students and scientists have visited the New Mexico since 1997 in order to sample vegetation at the Sevilleta and Jornada. Our major findings are that species diversity decreases as the aridity of the site increases, in that the diversity was highest at the SGS, and similarly low at the Sevilleta and Jornada. We also sampled species composition in patches dominated by either blue grama or black grama, and found that species richness and identity are very similar in both patch types. Our results indicate that subdominant species from the two biomes (Chihuahuan desert, shortgrass steppe) are not strongly associated with their respective dominant species.

*Cross-site Mycorrhizal Study (Edith Allen and Nancy Johnson).*

This research examines arbuscular mycorrhizal (AM) responses to N enrichment at five grasslands within the Long Term Ecological Research (LTER) network (Kellogg Biological Station in Michigan, Cedar Creek Natural History Area in Minnesota, Konza Prairie in Kansas, Shortgrass Steppe in Colorado, and Sevilleta National Wildlife Refuge in New Mexico). The principle objectives of this research are to: 1) characterize grassland mycorrhizae and their sensitivity to N eutrophication along a natural moisture and soil fertility gradient; 2) assess species composition changes of AM fungal communities due to N enrichment using microscopy and immunofluorescence; 3) assess responses of arbuscule:vesicule ratios to N enrichment; 4) conduct bioassays to test the hypothesis that fertilization may select for AM fungi that are inferior mutualists.

At all of the study sites except for Sevilleta, replicated experimental plots receiving 100 to 300 kg N/ha/yr (as $NH_4NO_3$) have previously been established by site personnel. In December 1995, we established twenty 5 x 10 m plots at Sevilleta, with half of the plots randomly selected and fertilized with 100 Kg N/ha/yr (half applied in June and half in December). At Shortgrass Steppe the N enrichment treatment was maintained only between 1971 and 1975, but at Kellogg, Cedar Creek, Konza, and Sevilleta, N is currently applied to the experimental plots once or twice a year. Early and late during the growing season, root and rhizosphere soil samples are collected from two dominant grass species (one that increases with N-enrichment and one that decreases with N-enrichment) in N enriched and control plots at each of the sites.

Data collection and analysis is nearly complete. Results indicate:
1) Arbuscular mycorrhizae are sensitive to N enrichment, arbuscular colonization is impacted at all 5 sites, but total colonization (including arbuscules, vesicles, coils and hyphae) is significantly impacted at four of the five sites. Total AM colonization at Sevilleta has not yet shown a significant response to the N treatment, but we expect a lag period between N enrichment and mycorrhizal responses. At the other extreme, there appears to be a lag period between the cessation of N enrichment and mycorrhizal responses. Although experimental N enrichment at Shortgrass Steppe ended 22 years ago, grasses in N-enriched plots still show significantly lower AM colonization than those in the control plots! Similarly, AM colonization at Kellogg and Cedar Creek was significantly reduced by N-enrichment.
2) Nitrogen enrichment impacts the species composition of spore communities of AM fungi. At Kellogg and Cedar Creek, N-enrichment significantly reduced spore populations of Gigasporaceae, indicating a shift in the species composition of AM fungal communities. Compared to the other grasslands, responses of mycorrhizae at Konza was reversed, N consistently increased AM colonization and spore populations of Gigasporaceae. We hypothesize that this result is due to an interaction between soil N and P. Konza soils strongly fix P and N:P ratios are much higher there than at the other sites. We hypothesize that adding N to Konza soils makes that system more P-limited and thus stimulates mycorrhizal colonization.
3) Arbuscule:vesicle data have not yet been completely analyzed, but so far, no consistent patterns have been observed in arbuscule:vesicle ratios.
4) Mycorrhizae are generally assumed to be mutualisms, however there are many cases in which they function as parasitisms. We hypothesized that, in undisturbed grassland systems, plants and AM fungi should be adapted to each other and to the local soil in order to maximize the mutualistic

effects of the symbiosis, however anthropogenic enrichment of limiting soil nutrients may perturb their mutualistic functioning. We tested the generality of this hypothesis for each of the five study sites by inoculating the two study grasses (one that increases with-enrichment and one that decreases with it) with AM fungi from either fertilized or unfertilized plots. Results of these experiments strongly support the hypothesis that fertilization generates inferior AM mutualisms for plants that typically depend upon mycorrhizae. These N-induced changes have no effect on plants that are non-mycotrophic.

## J. Public Outreach

Newspaper Articles/Television Broadcasts. The Sevilleta LTER Program has been featured on public television several times in the past year, and is participating in three productions for PBS/Educational TV. Numerous newspaper articles have quoted results produced by Sevilleta LTER researchers, including major stories in USA Today, U.S. News and World Report, The Scientist, Associated Press, and the local New Mexico papers (Albuquerque Journal, Albuquerque Tribune, the Socorro El Defensor-Chieftain, and the Farmington Sun-Times).

In 1998-99, the Sevilleta LTER was featured on the CBS, NBC, ABC, and CNN News in regard to possible Hantavirus problems associated with the 1998 El Niño. As a number of our predictions have come true, Sevilleta researchers Terry Yates and Robert Parmenter have been on national (CBS, ABC, NBC, CNN) and local news presentations discussing the relationships between climate, ecosystem productivity, animal populations and diseases. In addition, Parmenter also appeared on the CBS local news in June, 1998, explaining climate dynamics (droughts) and impacts on water availability and ecosystem responses in New Mexico based on the LTER studies. With respect to transfering LTER concepts and Sevilleta LTER results (as examples) in the international community, James Gosz has appeared on several television broadcasts in a number of foreign countries. This list includes appearances in Ireland, Spain, Taiwan (China-Taipai), Mongolia, and Israel.

The three PBS productions deal with (1) teaching the use of mathematics in solving problems using ecological experiments (the NSF-funded series, ``Math in the Middle of Nature''), (2) a program on biodiversity and the future of Man on the planet (another NSF-funded production, entitled ``Can We Survive?'', and based on Sevilleta LTER data integrated with a National Academy of Sciences symposium on global biodiversity), and (3) a series produced by UNM and the New Mexico Museum of Natural History entitled, “Ecosystems of New Mexico” that was broadcast to public school science classes throughout the state.

Public access to GPS CBS. Greg Shore (Sevilleta LTER GIS Specialist) designed and implemented a system for WWW and anonymous FTP public access to the Sevilleta LTER GPS Community Base Station (CBS) system. This provides C/A code and L1 phase code GPS base data access for all Internet-connected GPS users within a 300 km radius of the Sevilleta NWR. GPS-CBS information and WWW/FTP access is available at:
**http://sevilleta.unm.edu/data/archive/gps/**

## K. Student Programs

### UMEB/REU Program

The Undergraduate Mentorships in Environmental Biology (UMEB) Program (P.I. Robert Parmenter, plus many faculty mentors), a collaborative program with the Sevilleta LTER, finished its final year in spring 1999. In addition, in the summer of 1999, we started our renewed REU Site Program (P.I.'s Robert Parmenter and James Gosz) at the Sevilleta; the major emphasis of this program is to related biodiversity to ecosystem NPP in various ecosystem types across the Sevilleta NWR. As in prior years, the goals of these programs are to (1) instruct undergraduates in the principles of scientific research, (2) expose the students to a wide variety of ecological research techniques and career opportunities, (3) facilitate individual student research projects, and (4) encourage students to continue their scientific education in upper-division courses and graduate school. To accomplish these goals, the programs include (1) orientation meetings and a seminar series devoted to the variety of scientific opportunities in ecological research at the Sevilleta, (2) faculty-student one-on-one instruction of hypothesis development and research protocols in ongoing Sevilleta LTER projects, (3) field and laboratory experiences in sampling and data collection, (4) implementation of individual student research projects, carried out under the guidance of student-selected faculty members, and (5) preparation and submission of project manuscripts to scientific journals. These activities integrate all theoretical and technical aspects of the LTER and promote a holistic approach to large-scale ecological studies. Information on the new REU Site Program can be found at:
**http://sevilleta/research/outreach/reu/**

### Sevilleta Schoolyard LTER Activities

The Sevilleta's Schoolyard LTER Program is directed by Dr. Clifford S. Crawford, who has established our educational outreach program known locally as the "Bosque Ecosystem Monitoring Program" (BEMP). The major focus of this educational program is on the Rio Grande riparian cottonwood-forest ("bosque") corridor through central New Mexico (including the Sevilleta National Wildlife Refuge). The Sevilleta LTER Program has conducted a number of research studies in the Rio Grande bosque at Sevilleta NWR and other local sites, and due to its popularity with, and importance to, New Mexican populations (particularly schoolteachers and K-12 students), we have chosen this particular ecosystem in which to develop the Schoolyard LTER. The BEMP has four main educational goals. These are to (1) involve students and citizen volunteers of all ages in the coordinated monitoring of key processes and populations of the endangered Middle Rio Grande riparian forest ecosystem; (2) enable these participants to "learn by doing" about the natural history and ecology of the bosque near their communities; (3) use these students and volunteers to convey to their communities an appreciation of the scientific and social significance of long-term environmental research; and
(4) give the students and informed citizens an opportunity to become involved in the management of a critical environmental resource.

The BEMP uses mainly secondary school teachers and their students to collect data relevant to the long-term management of bosque functioning. Data collection occurs synchronously and according to a predetermined schedule. Thus, a given set of variables is sampled on the same date

at all four current BEMP sites. The sites are identical in layout and located between northern Albuquerque and the smaller city of Belen, NM, near the Sevilleta NWR. Site specific, abiotic data collected include soil and air temperature, precipitation and groundwater depth. Biotic data include litter production, plant diversity and indicator arthropod activity. Years of restoration related research on the bosque by UNM biologists have demonstrated the value of such data types and the relative ease of collecting them in the field.

In addition to the Director and Professor Cliff Crawford, the program is staffed by two coordinators and a data manager. The coordinators are biologists and educators associated with Bosque Preparatory School in Albuquerque, which pays the release time salary of one of them. Program interns have recently become an essential part of the BEMP. The 1998 Schoolyard supplement made it possible to award stipends to two of the most experienced interns. Another intern has an Undergraduate Mentorship Experience in Environmental Biology stipend awarded through the Sevilleta LTER. Each BEMP intern is assigned to work with site representatives (usually secondary school teachers) and individuals (usually their students) who collect the monitoring data following a brief period of training. Interns are responsible for supervising data sampling and for bringing sample material and field data records to UNM, where some additional sample treatment is performed by specially trained interns. The data manager then enters the data in a UNIX system operated by the Sevilleta LTER. Following data analysis, the data manager, in consultation with the director, will disseminate pertinent results to school classes, as well as government agencies that have managerial responsibility for the bosque and the Rio Grande; hence, the data from the Schoolyard LTER program actually is applied to real-world management issues.

The main activity in FY99/00 is to continue the operation of the existing program. This will include continued field sampling trips, sample analyses, and data management by the teachers, students, and interns. Another goal for the coming year is to finish the development of the databases and Internet homepage, so that the public (especially the teachers and students) can have easy access to the data sets as they develop. The BEMP data sets are currently being entered and archived on the Sevilleta LTER homepage, and should be completed during the proposed funding cycle (1999-2000). Homepage information on the Schoolyard LTER will include the Program Description (designed to recruit additional schools into the program), Goals and Hypotheses, Field Sampling Procedures, and the Data Sets: Weather, groundwater depths, vegetation composition, cottonwood tree demographic data, litterfall rates, and arthropod abundances. In addition, a major goal is to strengthen BEMP's community outreach and intersite communication. This will be accomplished through regular meetings, now underway, of staff and interns on the second and fourth Tuesdays of each month. The first meeting of the month is held at UNM and emphasizes intern reporting and intersite comparisons. The second monthly meeting is held at the Rio Grande Nature Center in Albuquerque and focuses on community outreach.

## L. Network-level Activities

*1. NASA/MODIS MODLERS Project*. Bruce Milne has a subaward from Oregon State University to participate in the NASA/MODIS MODLERS Project. This project brings together 14 Long-Term Ecological Research (LTER) Network sites and NASA's MODIS Land (MODLAND) Science Team for the purpose of locally validating Earth Observation System-era global data sets. For more information, see:
**http://atlantic.evsc.virginia.edu/~jhp7e/modlers/**

*2. LIDET Experiment*. Sevilleta continues to participate in the LTER Network, and has included the Sevilleta data in the project analyses.

*3. NASA Sun Photometer Calibration Study*. Sevilleta continues to maintain and service a Sun Photometer for NASA which is important for atmospheric corrections of satellite images.

*4. USDA/ARS Project*. Sevilleta is actively involved in supplying meteorological and evapotranspiration data to a USDA-ARS Global Change project that was integrating remotely sensed data with ground measurements of energy budgets and water fluxes.

## M. Additional Grant Support (21 Grants, Funding = $13,545,119)

Sevilleta LTER 1999 Supplement Proposal: REU Students, Research Equipment Upgrades, Museum Equipment Additions, and Schoolyard LTER Program Development, Intellectual Connectivity, and Mongolia International LTER Project. NSF, $401,000.

The Sevilleta Research Experiences for Undergraduates Site Program: The Relationship Between Biodiversity and Ecosystem Productivity. 1999-2002. NSF, $120,000.

Knowledge in Distributed Environments: Knowledge Networks of Biodiversity Information. James Beach and Leonard Krishtalka (P.I.'s); subcontract to UNM, Terry Yates (Co-P.I.) NSF, Total Award of $2,000,000; subcontract to UNM = $393,883.

Ecology of Hantavirus Enzootics: Immune Interventions. Brian Hjelle and Terry L. Yates. Department of Health and Human Services, 1 Aug 1997- 30 Jul 2002, $1,350,000.

Longitudinal Studies of Rodent Reservoirs of Hantavirus in the Southwestern United States. Terry L. Yates. Centers for Disease Control and Prevention, 1994-2000. $1,000,000.
Indian Health Services portion of same study adds $500,000.

Hantavirus Infections: Ecology, Immunity, and Treatment. Terry L. Yates and Fred Koster. Department of Health and Human Services, 1996-2000, $2,038,472.

International Collaboration in Infectious Disease Research: Environment, Ecology and Human Health in Chile: From Reaction to Proaction. NIH, 1998-2003, $4,000,000. Establishes long-term ecological research sites in Chile to study ecological aspects of hantavirus diseases; program

modeled after the Sevilleta LTER Program, with training of Chilean scientists and technicians at the Sevilleta Field Research Station using LTER database management techniques.

Development and Testing of an Immunological Sensor. NSF Engineering Grant, Terry Yates Co-P.I. NSF $285,000. Hantavirus field sensor is being built by UNM School of Engineering, and will be tested on Sevilleta LTER sites during rodent population sampling exercises.

Infectious Disease Training for Medical Students. NIH Grant to UNM School of Medicine, Collaborator Terry Yates. $400,000. This grant trains students on proper field and laboratory procedures for handling vector animals carrying infectious diseases.

Relocation and compactorization of the Museum of Southwestern Biology. Timothy Lowrey and Terry L. Yates. National Science Foundation, 1996-1999, $313,200.

Response of Southwestern Montane small mammal communities to global change. Terry L. Yates. US Fish and Wildlife Service, 1994-1999, $250,000.

Biological Diversity of New Mexico State Trust Land. Terry L. Yates. New Mexico Land Office, 16 Dec 1996 - 30 June 1999, $10,000.

Replacement and consolidation of research training facilities of the Department of Biology, University of New Mexico. Terry L. Yates, Robert R. Parmenter, and Howard Snell. National Science Foundation,1997-1999, $960,000 + $2,300,000 matching funds from UNM. NOTE: This project will fund the renovation of a UNM campus building which will house the new offices, laboratories and museum collections of the Sevilleta LTER Program and the LTER Network Office.

Ecosystem and Soil Studies of Native American Runoff Agriculture. NSF, $476,713. P.I.: Jonathan A Sandor, Iowa State University (ISU); Co-P.I.s: Mark Ankeny, Daniel Stephens, Carleton S. White, Stephen E. Williams, and Deborah A. Muenchrath.

Water Quality Study in the Santa Fe Watershed. USDA Forest Service. $20,000. PI: Carleton S. White.

Ecology of Fire in Semi-arid Grasslands. USDA Forest Service, $24,876. P.I. Carleton S. White.
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USGS Paleoecological Research at the Sevilleta LTER. DOI, U.S. Geological Survey, Global Change Program: The paleoecological work at the Sevilleta LTER has been done through cooperative agreements where at least half of the resources have been contributed by USGS.

U.S.-Hungary Grassland Comparisons: Response of Vegetation to Environmental Constraints and Global Change. Coffin, D. P., and J. R. Gosz. NSF International Programs (INT95-13261). $156,076. 1996-1999. Collaborative project with Hungarian ecologists (Edit Kovacs Lang, Sandor Bartha, and Gabor Fekete) funded by the Hungarian Academy of Sciences.

CAAW: Development of Landscape Analysis Techniques and GIS Expertise to Predict Vegetation Dynamics at Ecotones. Coffin, D. P. NSF Career Advancement Awards for Women (DEB97-07100). $47,380.

Riparian ecosystem restoration: effects of flooding and vegetation type on annual evapotranspiration in a semi-arid landscape. P.I.'s Cliff Dahm, Manuel Molles, Jr., Cliff Crawford, Padinare Unnikrishna, Maury Valett, and Terri Mulhern. NASA, $700,000, 2/1998-2/2001.

Mycorrhizal Responses to Nitrogen Eutrophication at Five Mesic to Semiarid Sites. (1/96-12/31/98) DEB-9796168 (initially to Univ. of New Mexico as DEB-9527317): $98,519 , P.I. N.C. Johnson, E.B. Allen is a collaborator with grant DEB-9526564.

## N. 1998-Present Sevilleta LTER Publications (Total = 46)

[Note: Publication numbers refer to the Sevilleta LTER Bibliographic Listing.]

**Journal Publications: (Total = 33)**

99 Post, D.M., J.P. Taylor, J.F. Kitchell, M.H. Olson, D.E. Schindler, and B.R. Herwig. 1998. The Role of Migratory Waterfowl as Nutrient Vectors in a Managed Wetland. *Conservation Biology*. 12(4):910-920.

103 Parmenter, Cheryl A., Terry L. Yates, Robert R. Parmenter, James N. Mills, James E. Childs, Mariel L. Campbell, Jonathan L. Dunnum, and Janie Milner. 1998. Small mammal survival and trapability in mark-recapture monitoring programs for *Hantavirus*. *Journal of Wildlife Diseases.* 38:1-12.

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