2001-2002 Annual Report, Sevilleta LTER Program (NSF Grant 0080529)

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I. Activities: Introduction and Conceptual Background of the Sevilleta LTER.

The Sevilleta LTER research site is located on the Sevilleta National Wildlife Refuge in central New Mexico where a junction of four biomes (Great Plains Grassland, Great Basin Shrub-steppe, Chihuahuan Desert and Montane Coniferous Forest) provides a rich assortment of ecotones or Biome Transition Zones (BTZs). Interacting with a highly variable climate, the large area (100,000 ha), elevational range (1,350 – 2,797m), complex topography, geology, and soils, provide a complex spatial and temporal template for these BTZs. The Sevilleta is one of the few places in the world with a major research program dedicated to examining the edges of these biomes through long-term research and an increasing array of collaborative, short-term research efforts that range from genetics to remote sensing of the landscape. We are focusing on the floral and faunal properties of transitions between grass and shrub life forms represented by two components of the Chihuahuan Desert biome and their junctions with the Great Plains shortgrass steppe biome. We study: 1) specific roles of species and ecological processes that contribute to the structural and functional properties of the biome transition zone; 2) nonlinear relationships (i.e., ecological thresholds) manifested in space and their controls (e.g., top down vs. bottom up processes); 3) hierarchical relationships among processes at multiple scales; and 4) BTZs as the sources of enhanced species diversity.

Our work is building upon and expanding our studies since 1989. This year we have initiated new long-term landscape experiments and measurements to develop and test a general theory of the dynamics of Biome Transition Zones. Our new conceptual framework expands our past studies to focus on patch-scale dynamics, biotic and abiotic drivers, and the consequences of different patch types, sizes, and their mosaics to landscape and regional scale dynamics. We are initiating a series of experiments focused on the importance of plant-soil-animal-microbe interactions and feedbacks with ecosystem dynamics. Our iterative approach of combining a synthetic simulation model with data collected from short- and long-term interdisciplinary studies are providing a framework for extending our conceptual model to additional ecotones in the future.

Our findings provide an important regional context for studies conducted within the shortgrass steppe biome at the SGS LTER and within the Chihuahuan Desert biome at the JRN LTER. Future studies will expand to other major biome representatives at Sevilleta (e.g., shrubsteppe of the Colorado Plateau, piñon-juniper woodlands, and river/riparian bosque). These studies on other BTZs and ecotones present on the Sevilleta will further develop and test BTZ theory applicable to understanding and predicting ecosystem response to global change. We will use simulation modeling to predict changes in the location and composition of BTZs through time under changes in climate and disturbance regime. Because the region is experiencing an extended drought, possible directional changes in temperature, and increases in atmospheric deposition, an understanding of the key processes driving patch and ecotone dynamics is critical to our ability to manage and preserve the biodiversity and natural resources of these systems. We expect to find common properties and patterns that can be used for many types of boundaries at many scales. Extrapolating from patch mosaics, processes, and dynamics to the landscape and region will also be critical in determining the contribution of the Sevilleta to regional and global biodiversity and biogeochemical cycles.

During 2001-2002, Sevilleta researchers continued field work for a number of projects to characterize long-term dynamics in a range of abiotic and biotic variables in the core ecosystems of the Sevilleta. These studies included meteorological measurements, NPP, vegetation transects across ecotones, vegetation mapping, rain-out shelter experiments, long term population studies of vertebrates and invertebrates, nutrient cycling and decomposition studies, a cross-site small mammal exclosure study, and a large number of graduate student and undergraduate REU/UMEB student projects. Results of these studies are presented in the Findings Section of this report. Since 2000, the Sevilleta LTER has led to the publication of 92 journal articles and 27 book chapters, reports and theses/dissertations.

II. Findings.

The results of the 2001-2002 research activities are reported below. In total since 2000, when the LTER-III funding cycle began, the Sevilleta LTER Program has supported the production of 92 peer-reviewed scientific journal articles and 27 book chapters, reports and theses/dissertations.

Weather Results: Sevilleta is into its 14th year of meteorological data collection. Sevilleta climate studies this past year continued to look at conditions at multiple scales both spatially and temporally. There has been an increased focus on the shrub to grassland transition area of the northeast side of the Sevilleta. This resulted in some changes in the meteorological monitoring array. The most important aspect of this was the installation of a new weather station at the new site on McKenzie Flats. This site is located in an area dominated by blue grama grass (*Bouteloua gracilis*). In addition, a new partial station that measures temperature and precipitation was installed at a site close to Black Butte (~10 km NW of the blue grama grass site). The Sevilleta LTER also contributed to the purchase and installation of a new eddy covariance system to measure both water and CO_2 fluxes in the vicinity of the Deep Well meteorological station (black grama grass core study area). This was installed as part of the "Big Foot" Project, with which the Sevilleta LTER Program is a close collaborator. All of this provides a better ability to monitor conditions across the shrub to grassland transition on McKenzie Flats.

During 2002, the Sevilleta has been experiencing drought that affected much of the West during this past year. Despite the apparent shift of the El Niño Southern Oscillation (ENSO) pattern away from the cold status (La Niña), which it had been locked into since the end of the 1997-98 El Niño, Sevilleta's climate during the 2002 water-year was most similar to La Niña conditions of 1996. The fall, winter spring period was very similar to that experienced during La Niña events in 1988-89 and 1995-96. Figures 1-3 show precipitation and temperature over the Sevilleta during the past water year. Moisture and temperature during the winter, and especially during the early spring, were at the dry and hot extremes for this area. The North American Monsoon was late in setting up and was ultimately rather short-lived. The Sevilleta did benefit from several sizeable storms that brought at least average moisture to the Sevilleta in late July and early August. A September storm brought the water year back from the brink of being the driest water year in the 14-year history of the Sevilleta LTER.

Although drought is pervasive in most of the western United States, the average monsoon moisture coupled with a direct hit from some Pacific-derived dissipating tropical storms combined to push the mid-Rio Grande Climate division into the wetter than normal status according to the Palmer Drought Index at the end of the water year. This condition is local in area and very possibly in time as well but considering the timing of the precipitation it may have effects that get carried into 2003.

Climate monitoring on a broad scale temporally and spatially is focused upon the possibility of long-term drought conditions, such as occurred from 1949-1956 in the Southwest. Sea-surface temperatures in the North Pacific and North Atlantic are similar to those present during the 1950s drought. The recent shift of the Pacific Decadal Oscillation (PDO) into the cool phase may ameliorate positive effects of El Niño on precipitation predicted for 2002-2003, as was seen during the extended drought of the 1950's. The extended conditions of drought in the Rio gRande basin of New Mexico is shown in Figure 5. Spring snowmelt discharge for 2000, 2001, and 2002 were all below the long-term average. A long-term moisture deficit has developed over the past three years in the region.

Figure 1.

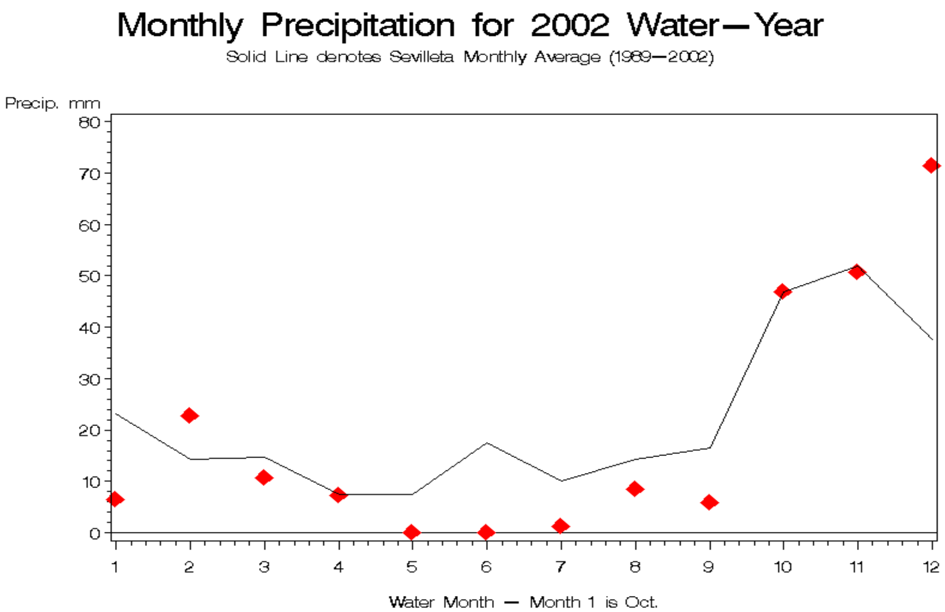


Figure 2.

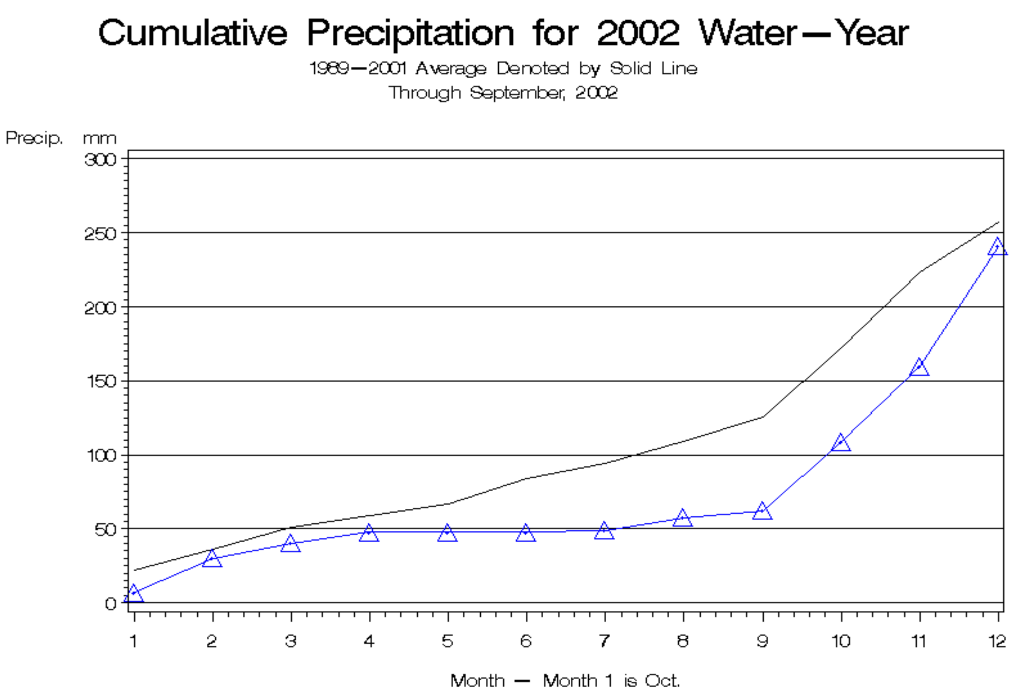


Figure 3.

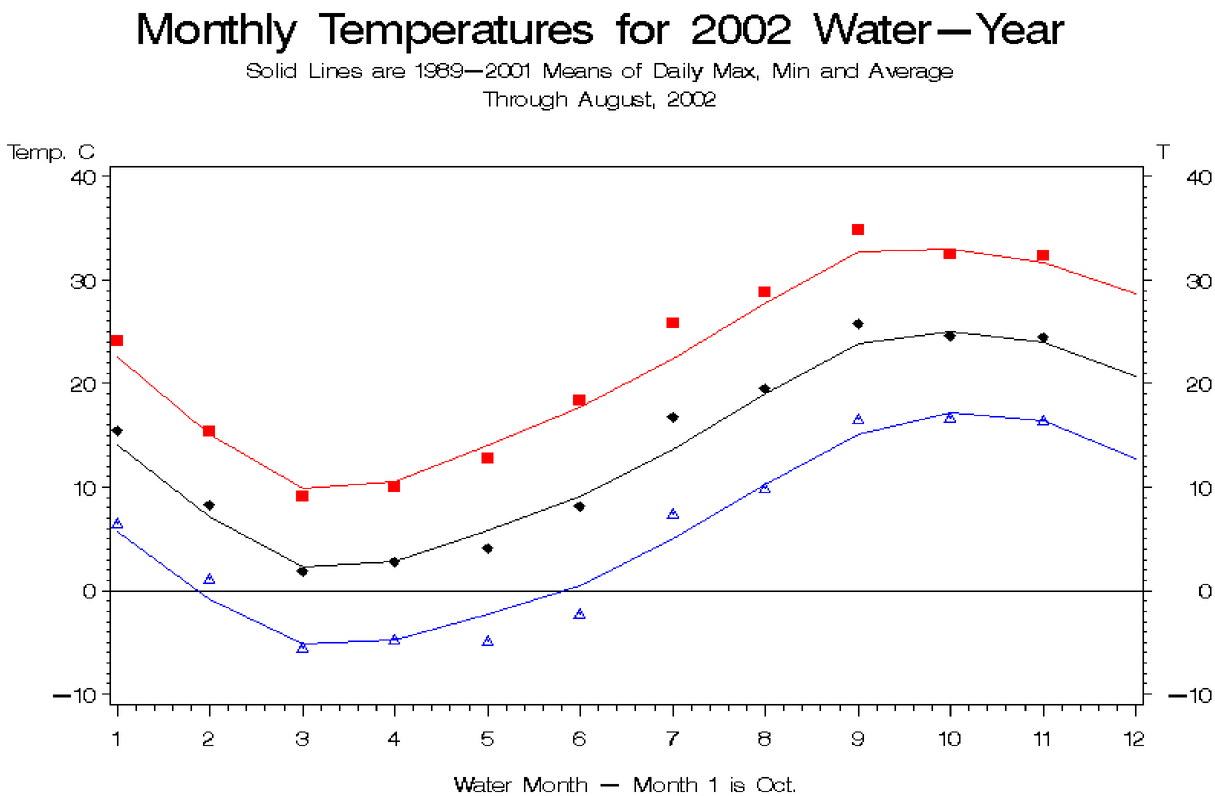
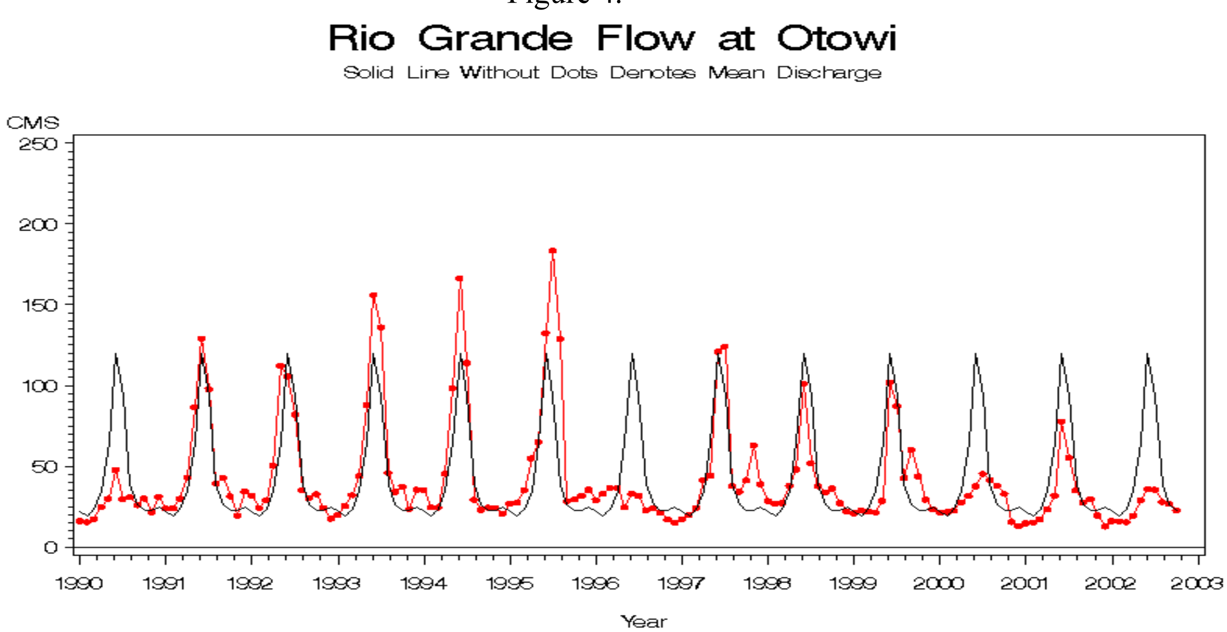


Figure 4.



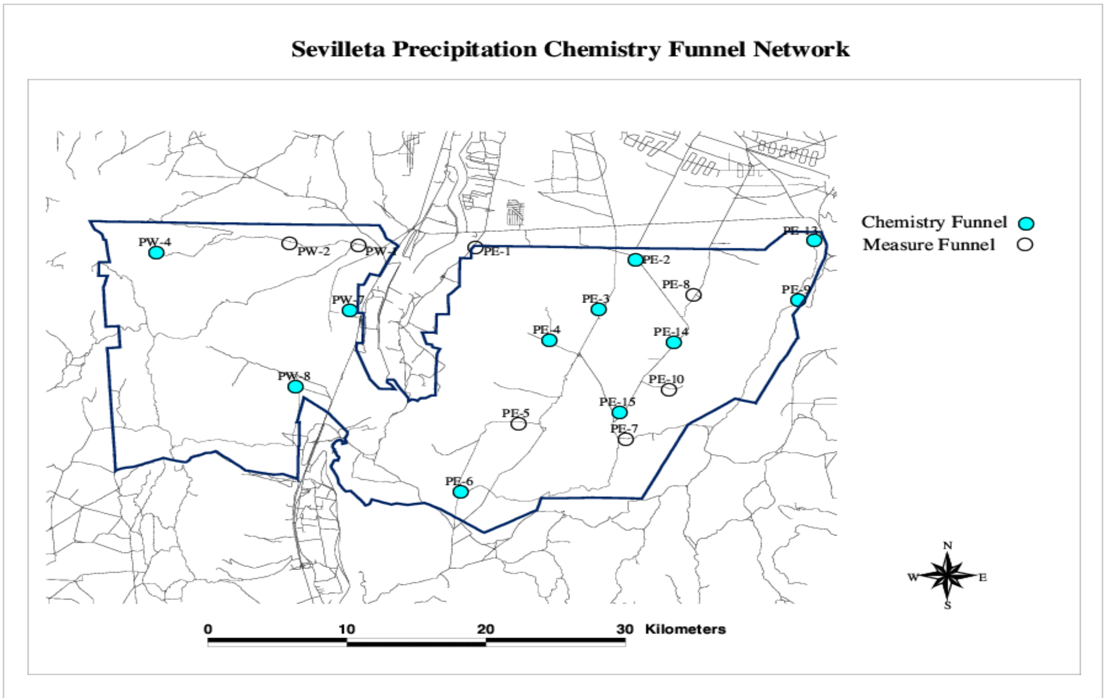
Precipitation chemistry. Inorganic nutrient chemistry has been analyzed on precipitation from the Sevilleta for almost 14 years. These analyses are performed on samples collected monthly at numerous locations across the refuge. Chemistry was run to determine inputs of nutrients across the refuge on both a spatial and temporal basis. Past results have shown that magnitudes of fluxes were mostly directly correlated with precipitation amount while precipitation amount was most strongly correlated with elevation. Seasonally, precipitation is dominated by the monsoon moisture of the summer. While there may be considerable variation in seasonal precipitation annually, the long-term total for the July-September period is just about equivalent to the total for the other nine months of the year. Likewise, fluxes of important nutrients such as NO3, NH4 and K are equally split between monsoon and non-monsoon precipitation (Table 1).

Table 1. Nutrient inputs from precipitation at the Sevilleta LTER research site (2001-2002).

		Average Fluxes (mg/m^2)							
Period	mm	NO_3-N	NH_4-N	SO4	Cl	Na	K	Ca	Mg
Oct-Jun	122.4	43.3	52.1	199	31.1	22.0	22.1	160	14.3
Jul-Sept	138.4	43.2	60.5	202	24.5	10.2	18.2	110	10.6
Total	260.8	86.5	112.6	401	55.6	32.2	40.3	270	24.9

Spatial variability in precipitation and nutrient fluxes across the Sevilleta was found to be much less than interannual variability. Consequently, the number of locations at which samples were collected for chemical analysis was reduced in 1997 from 20 to 6. However, with the increased emphasis on measuring changes across vegetation transition zones on the Sevilleta, a new sampling design was phased on the east side of the Sevilleta. As of 2002, chemistry is being analyzed on samples from 11 locations across the refuge (Figure 5). Seven of these sites span the gradient from creosote bush shrub-land up the elevation gradient to the piñon-juniper woodland. There is also continued interest in measuring what influence the down-valley flow of air from the Albuquerque metropolitan area to the Sevilleta may have on precipitation chemistry. This new design may better quantify the potential influence of urganization north of the Sevilleta NWR.

Figure 5.



Decomposition/Nutrient Cycling: The Sevilleta's long-term Plant Litter Decomposition Project is an eleven-year study that is currently completing data comparisons and analysis. The study's main objective is to determine decomposition rates of dominant plant species over a range of biomes in relation to climatic variation. The effects of this variation are compared within and between each environment over the time line of a decade.

Changes in location and litter type have occurred since 1989 in response to the placement of meteorological stations thoughtout the Sevilleta. The long-term litter types include *Bouteloua eriopoda, Oryzopsis hymenoides, Juniperus monosperma,* and *Larrea tridentata.* Other litter types used at times during the study consist of *Bouteloua gracilis, Pinus edulis, Yucca glauca, Atriplex canescens, Populus deltoides* ssp. *wislizenii, Festuca arizonica,* and *Populus tremuloides* ssp *michx.*

Biome and transition areas between biomes determined site location. Some were discontinued and others moved in relation to whether other data associated with the site would be available for use in order to explain why decomposition may or may not vary at one site versus another. There were originally nine sites along an approximate north-south transect from grass habitat to creosote habitat, as well as two sites off the Sevilleta, one at Bosque del Apache and the other in the Magdalena Mountains. Years 1991-1998 included four sites: Cerro Montoso, a piñon-juniper forest and the wettest of all locations; Deep Well, a short-grass prairie site; Rio Salado, a Chihuahuan desert site; and Red Tank, a Great Basin shrub-steppe site. Changes in 1998 occurred in efforts to conserve resources and to address changes across vegetation transition zones. The Cerro Montoso and Deep Well sites were continued with the addition of Blue Springs, a juniper-short grass prairie mixture, and Five Points, a creosote area near the Deep Well short grass-desert grass area. The latter two sites were included along with installation of new meteorological instruments.

Presently, we are analyzing mass data, and completing carbon-nitrogen ratio data. Nearly 5,000 C:N samples have been processed, including all time 0, year 1, and year 2 samples for all sites. Samples from the Deep Well site that were collected at intervals between time 0, year 1, year 2 and year 3 are currently being processed.

Preliminary analysis of data from the Deep Well site indicate that annual precipitation is not correlated with the first year's mass loss for either of the grasses *Oryzopsis hymenoides* ($P = 0.66$) and *Bouteloua eriopoda* ($P = 0.13$), or the shrub *Larrea tridentata* ($P = 0.89$). For these three species, the first year's mass loss was not correlated with C:N values at time 0 at this location (*Bouteloua eriopoda* ($P = 0.53$), *Oryzopsis hymenoides* ($P = 0.45$), *Larrea tridentata* ($P = 0.76$). The differences between species in magnitude of decomposition (Fig. 6) in different years suggest that a single unifying mechanism driving decomposition is unlikely to be identified in this ecosystem. Site properties, climate, and litter quality, determined by the previous year's climate and nutrient resource availability, may all interact to yield species-specific patterns of decomposition through time.

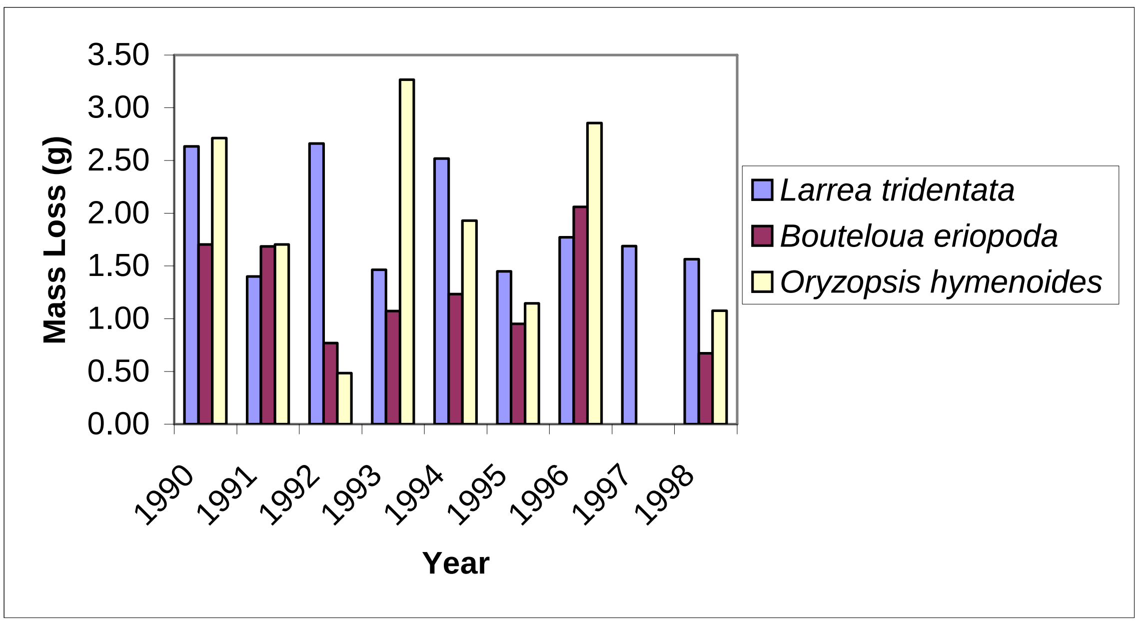


Figure 6. First year mass loss of three species at the Deep Well site, 1990-1998.

Belowground activities. In 2002, we have focused our root dynamics field studies on updating minirhizotron analyses. New minirhizotron tubes were placed in the grassland- and creosotebush-dominated sites in spring and summer of 2002, and will be placed in patches in fall of 2002, so that they will be stabilized and ready for reading by spring 2003.

Tubes operating since 1997 include those placed under piñon pines and juniper trees (in the Goat Draw study area), and in blue grama grass, black grama grass and creosotebush sites (McKenzie Flats). We are completing reading of existing images. A final set of tubes will be placed in late fall including split tubes in which root tip samples can be taken for molecular and isotopic analysis.

Images are being collected and analyzed for comparative relative root and mycorrhizal number. There is considerable variability among plant species. An example is from September 2001. Blue grama root numbers per 100 cm^2 of root tube were 134 (SEM 3.1), compared with 115 (SEM 4.5) in mixed creosotebush/grama grass,128 (SEM 0.8) in juniper, and 104 (SEM 2.1) in piñon pine. If we look at changes through time, there is considerable variability in individual times. An example is the root numbers in juniper and pines (Fig. 7). In juniper, root numbers ranged from a mean low of 55/100 cm^2 in June of 1998 to a mean high of 162/100 cm^2 in July of 2002. In piñon pine, the root numbers ranged from a low of 83/100 cm^2 in August of 2000 to a high of 139/100 cm^2 in 2002.

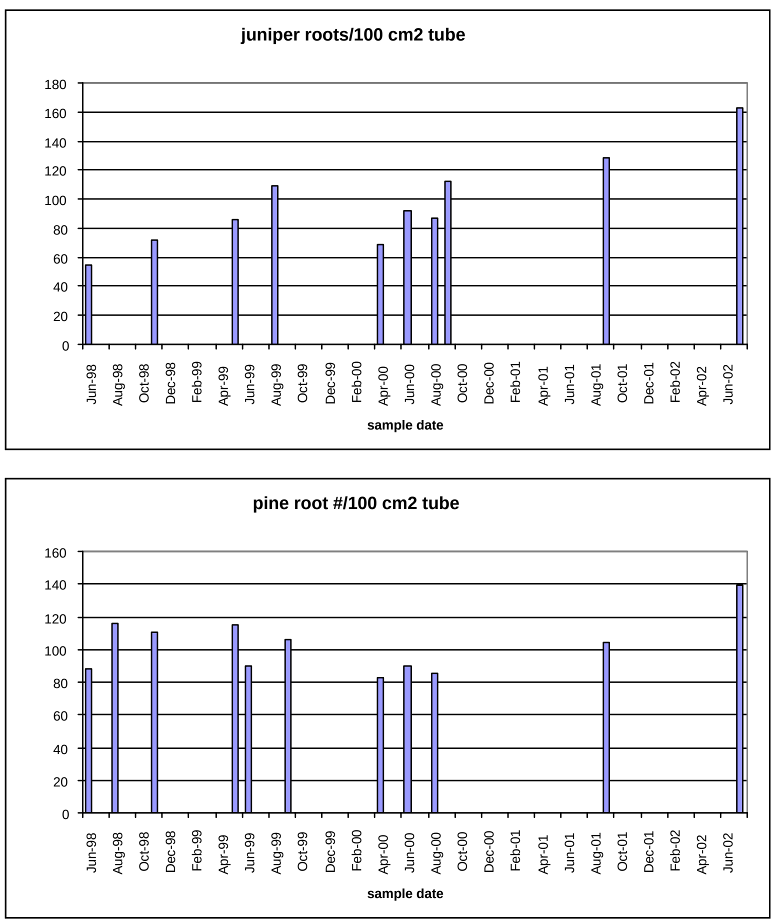
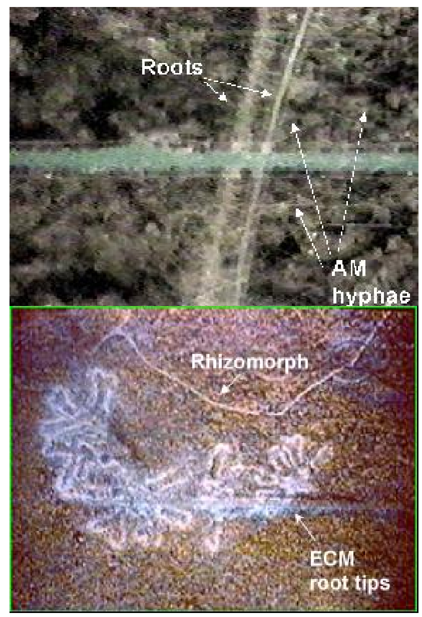


Fig. 7. Temporal dynamics of root numbers in juniper (top) and piñon pines (bottom).

The variation clearly indicates a need to calibrate root numbers, root length, diameter (to assess mass), and mycorrhizal infection. We are currently completing this analysis for juniper and pine. An example data set is shown below. We will then apply this analysis to creosote and grass roots.

Year	Juniper root length (cm/tube)	root # (/tube)	% AM	AM root length (cm/tube)
1998	26	55	65	17
1999	25	109	20	5
2000	17	87	45	8

These data will be integrated with root biomass data to develop analyses of root production. Analyses of all existing root and mycorrhizal observations are on-going.



Mycorrhizal structure**.** Arbuscular mycorrhizal plants have highly variable % infection. At this stage, it is difficult to separate the effects of root expansion from infection dynamics. Past root infection at the SEV LTER ranged from 20 to 70% of the root length in the grasslands and from 10 to 70% in juniper. We will be analyzing mycorrhizal infection by looking at the relative numbers of roots infected using direct minirhizotron observations. Based on the architecture of radiating hyphae from just behind the region of elongation, we can calculate the numbers of infections.

Ectomycorrhizal dynamics have been studied for pinyon pine. The root tips of pinyon pine are generally mycorrhizal. A relatively high number of mycorrhizal tips can be observed and studied through time (Fig. 8).

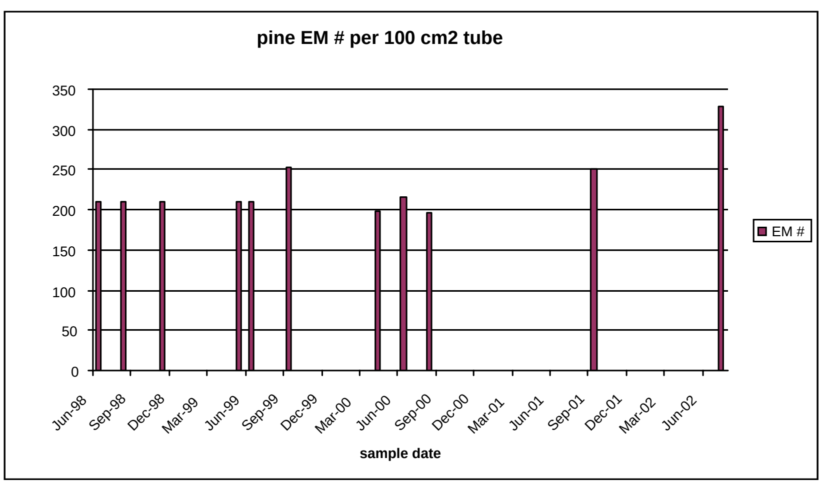
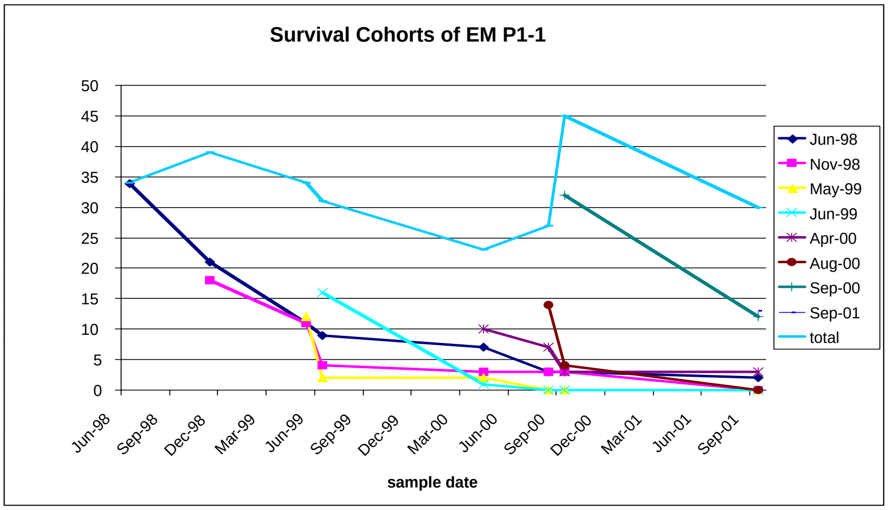


Figure 8. Numbers of piñon pine root tips infected with ectomycorrhizal fungi.

Just as importantly, we can begin to assess life spans of individual mycorrhizae using morphotypes distinguishable using the minirhizotron. Our observations from a single plot (remainder being analyzed) indicate that individual mycorrhizal fungi have highly variable life spans. Most exist for only a few weeks but some may persist for up to three years (Fig. 9). This supports the ^{14}C data showing high variability in root tip data age but some up to 3 or 4 years.

Figure 9. Temporal dynamics of survival of mycorrhizal fungi.



Nitrogen fertilization studies. We have continued N fertilization studies in grassland and in the pinyon/juniper. Grassland fertilization studies were initiated by Nancy Johnson (NAU) and Edith Allen (UCR). Minirhizotron tubes were installed in spring of 2002 and we are analyzing the first results. Previous AM studies are being analyzed (N. Johnson and E. Allen, pers com). Piñon/juniper fertilization studies were initiated in 1997 by K. Pregitzer (MTU), M. Allen (UCR), R. Hendrick (U GA), and R. Ruess (U AK). By this time, we are able to demonstrate important changes in responses to N. In the pine, leaf N was 1.13% in control and 1.36% in fertilized plants. In the same plants, leaf P was 0.17% in control and 0.11% in N fertilized plants. N/P ratios were 6.5 in control and 12.4 in fertilized plant leaves. This would suggest that, based on N:P stoichiometry, the fertilized plants are closer to optimal N:P ratios. However, the response was a significant lowering in P concentration along with the increase in N.

This also changed belowground responses. No differences in root numbers were observed; however, mycorrhizal tip density initially was lower than in fertilized plots (1998-9) but switched by 2000 to 2002 in control plants (Figs. 10 and 11). In association with this lowered mycorrhizal activity, mortality of several trees in fertilized plots was observed, but none in controls, and appeared to be associated with severe drought.

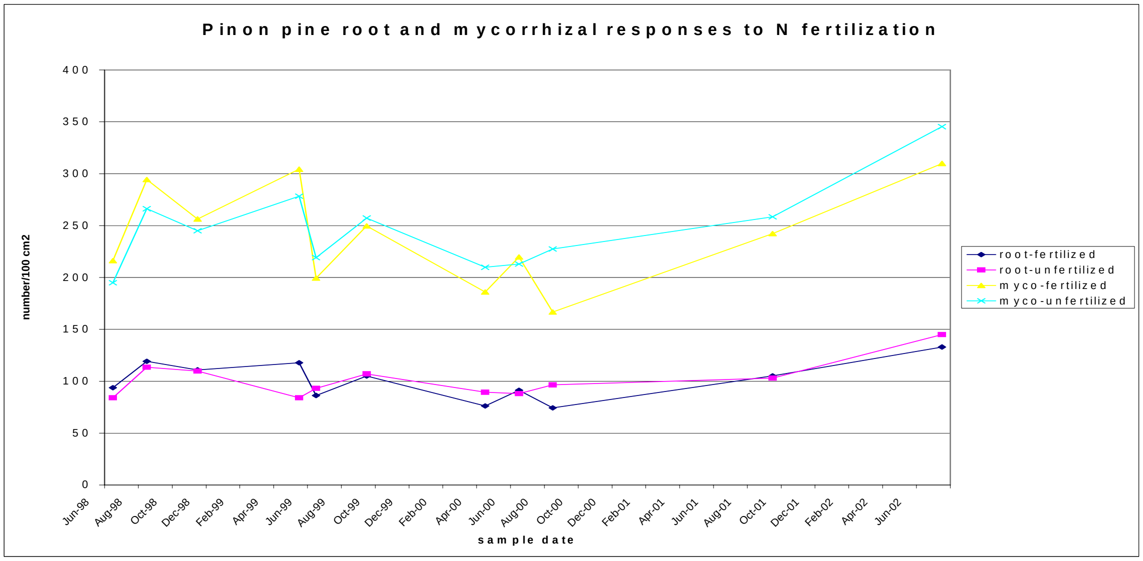


Figure 10. Dynamics of piñon pine root tips in N-fertilization study.

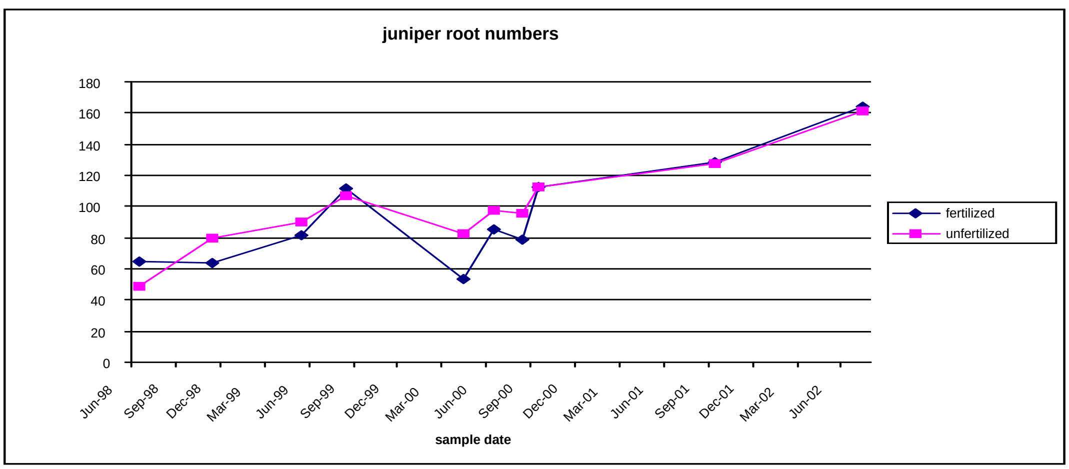


Figure 11. Dynamics of juniper root tips in N-fertilization study.

Alternatively, N:P ratios went from 8 in control leaves to 13 in N-fertilized plant leaves in juniper. N concentrations went from 0.8% to 1.3% whereas P concentrations did not change (0.1% in both treatments). No changes in root or mycorrhizal activity were observed. Plants remained healthy in both treatments.

Stable isotope tracer (15N) studies. Vegetation plays a central role in structuring desert ecosystems by modifying local environmental conditions. For instance, creosotebush creates a favorable microclimate for saguaro seedlings under its canopy and influences plant succession in the lower Sonoran Desert. By increasing soil moisture and protecting understory soils from the effects of high temperature, shrubs also help to retain soil nitrogen (N), increase soil organic matter, and create local microsites for microorganisms.

Microbial populations benefit from these environmental modifications as evidenced by increased biomass and activity under the shrub canopy. Under shrubs, the accumulation and concentration of wind-blown materials, the addition of nutrients that have been recycled from plant litter, and greater microbial activity contribute to the formation of "islands of fertility" in the Great Basin, Mojave, and Sonoran Deserts. Invading shrubs may modify both the physical and biological environment, affecting regional climate across the southwestern United States. It is thought that resource islands under long-lived shrubs may regulate abiotic and biotic interactions in semiarid ecosystems and function as a positive feedback mechanism for continued desertification.

Studies concerned with the spatial structure of desert vegetation often ignore the main consequence of switching from a grassland to a shrubland — changes in the spatial heterogeneity of desert vegetation lead to pronounced changes in the biogeochemical cycles of soil nutrients. In semiarid regions, perennial grassland typically exhibits a uniform distribution of bunchgrasses and soil resources; whereas, perennial shrubland creates a patchy distribution of vegetation and soil resources across the landscape. Vegetation structure may be important to the redistribution of plant essential elements, such as nitrogen, with time. Such a redistribution of essential elements may influence the development of patches in the biological transition zone (BTZ) at the Sevilleta National Wildlife Refuge, as in other semiarid ecosystems.

Because an earlier study suggested that shrubs and grasses induce different spatial distributions of many soil nutrients, we decided to examine the redistribution of nitrogen in grassland and shrubland soils. We used the stable isotope tracer, nitrogen-15 (15N), to follow the fate of nitrogen in grassland and shrubland sites along the ecotone between the Chihuahuan Desert and the Central Shortgrass Prairie, where we expect the changes to be most pronounced and where the history of vegetation change is well documented.

We tested the hypothesis that the rates and patterns of soil nutrient loss over time will differ between the grassland and shrubland for a limiting, plant-essential element, i.e., nitrogen (Fig. 12). We predicted that in spatially uniform grassland the coefficient of variation in added 15N would remain constant with time, but in a spatially patchy shrubland, the coefficient of variation in added 15N would increase with time. The coefficient of variation in 15N in time should reflect the spatial patchiness of the vegetation. This long-term 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.

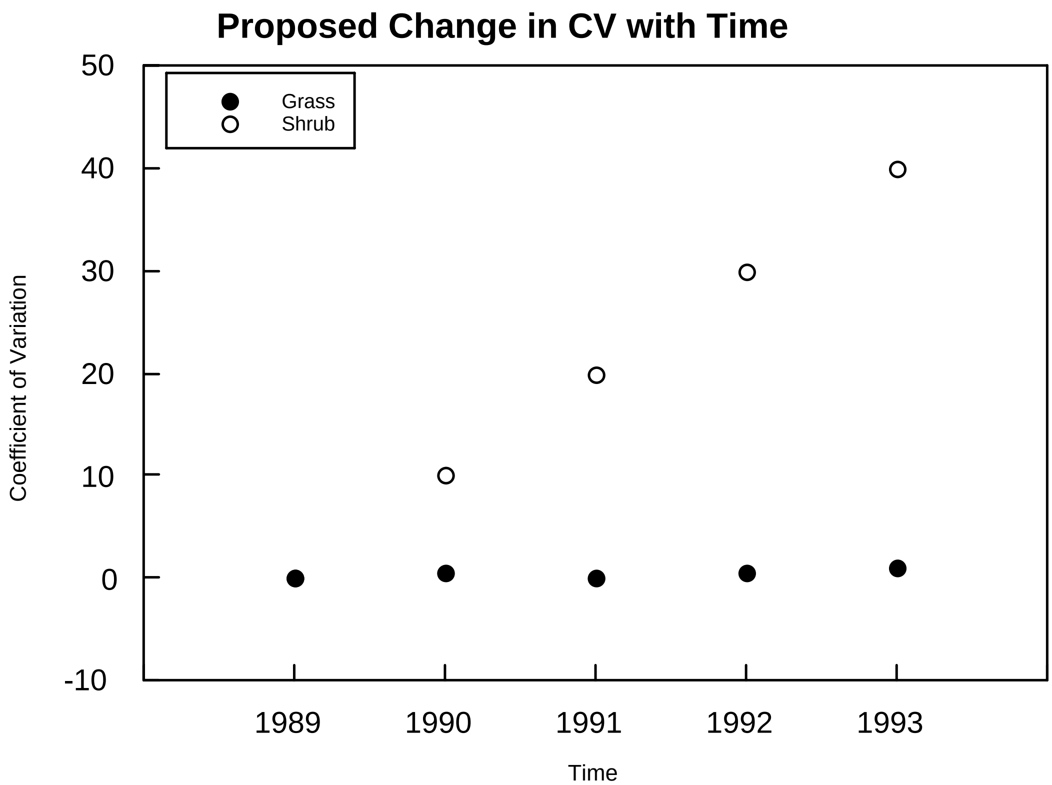


Figure 12. Expected change in CV following application of a tracer in 1989. Grassland, where vegetation is spatially uniform, should show little increase in spatial heterogeneity of plant -essential elements (N and K). Shrubland, where vegetation is spatially patchy, should show a marked increase in the spatial heterogeneity of plant-essential elements.

Tracer Application and Analysis. We applied a tracer to study the loss of representative soil nutrients from ten 15.25-cm diameter points arranged in a stratified random design in each of the four 10 m x 10 m plots in the grassland and shrubland. In order to simulate the movement N, we applied $^{15}NH_4$ in the form of $^{15}NH_4Cl$ to the surface soils. The $^{15}NH_4Cl$ (0.33 g) tracers were dissolved in 500 ml of deionized water and applied to 10 sites per plot in 50-ml aliquots in July 1989. The first soil samples were taken 2 days following the spike application.

The site of each spike application was sampled annually during the summer in 1989, 1990, 1991, 1992, and 1993, then in the summers of 1999 and 2001. Two samples with a volume 28.5-cm^3 were removed from the site of spike application, which had a total volume of 1815 cm^3 to 10-cm depth. Each sample contained a small percentage of the total soil volume, about 1.5%. All samples were air-dried, sieved, and shipped to Duke University, for the first five summers, and subsequently to the University of New Mexico (UNM). Ground soil samples were analyzed for ^{15}N on a mass spectrometer at Duke

University and UNM. Values reported from the mass spectrometer equal #^{15}N atoms/(#^{15}N atoms + #^{14}N atoms per sample).

We analyzed the concentrations of ^{15}N tracers using the coefficient of variation (CV), as an index of spatial heterogeneity, and used regression analysis to estimate the rate of loss of the tracers from the ecosystem. The CV, representing the variability in the amount of each tracer in a spike application site, was calculated for 40 samples from the grassland and 40 samples from the shrubland each year (1989-1993; 1999, 2001).

Over the first five years, ^{15}N concentrations in the grassland were at least twice ^{15}N concentrations in the shrubland, and more of the original spike application remained in the grassland over time (Figs. 13 and 14). But, based on ANCOVA analysis, the loss rates are not significantly different between vegetation types. After the first year, about 60 % of the original ^{15}N spike was lost from the grassland sites, where a slightly higher, but non-significant, concentration remained under grasses than between grasses. In the shrubland, slightly over 80 % of the original ^{15}N spike was lost in the first year, and more was lost from between shrubs than under shrubs. ANCOVA results indicate that while the slopes for under shrubs and between shrubs are not the same, a significant interaction between the covariate (year) and the treatment (cover) makes it difficult to separate the effect of cover from that of year.

We calculated changes in the CV, the standard deviation divided by the mean, for ^{15}N remaining over five years and eleven years, as an index of spatial heterogeneity of the spike with time (Fig. 15). We expected the CV of ^{15}N to increase with time in the shrubland as nutrient redistribution reflected the spatially heterogeneous shrubland vegetation and the CV in the grassland to remain constant over time reflecting the spatial uniformity of grassland vegetation (Fig. 12).

CVs for ^{15}N were similar in both vegetation types, increasing the first year following the spike application, and remaining unchanged, at about 40 % in both vegetation types for 1990-1993. In soils sampled prior to the spike application in 1989, the background CVs for total N (rather than ^{15}N) was 28 % in the grassland and 21 %, respectively, in the shrubland. Following the spike application, CVs increased for the 15N tracer element in both vegetation types (Fig. 15). In the grassland, approximately 15% of the original 15N tracer remains, and while the CV shows a general increase with time for the grassland (Fig. 15), there appears to be little difference in the CVs in 15N under grasses from those in the intergrass spaces (Fig. 16). In the shrubland, the amount of tracer remaining is less than 5%. In the shrubland, the general increase in CV with time differs from the grassland. In the shrubland, there is a marked difference between 15N tracer under shrubs and in the intershrub spaces. The CV between shrubs is very low (Fig. 17), but is higher for the intershrub spaces. This trend is apparent for only the 2001 samples and may reflect the change in analytical laboratories. The 2002 samples are currently being analyzed. For experiments that use repeated sampling of tracer elements at the same location, CV may not be the most appropriate or useful estimate of changes in the spatial heterogeneity of soil nutrients over time.

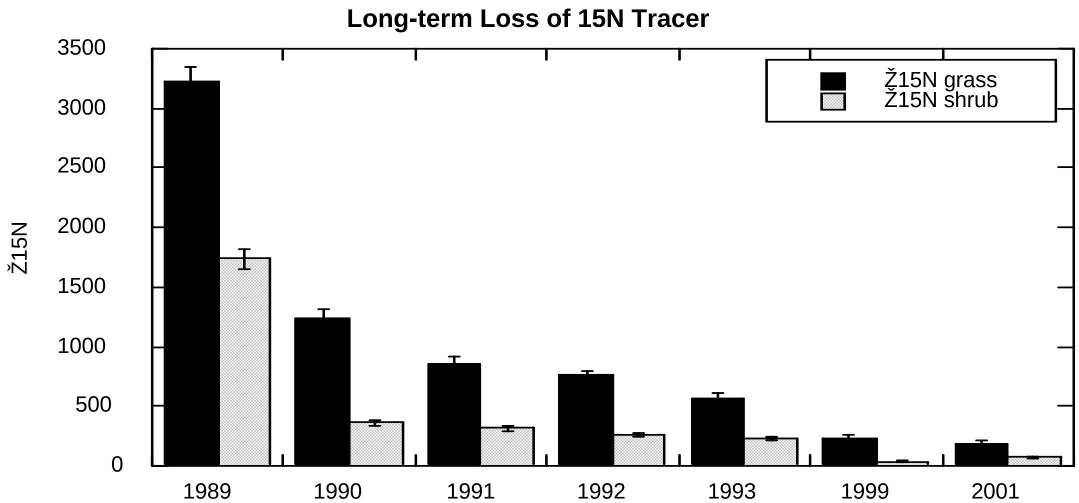


Figure 13. Changes in delta 15-nitrogen (∂ 15N) with time in Sevilleta grassland and shrubland. Values are reported as #^{15}N atoms/#^{15}N atoms + #^{14}N atoms per sample.

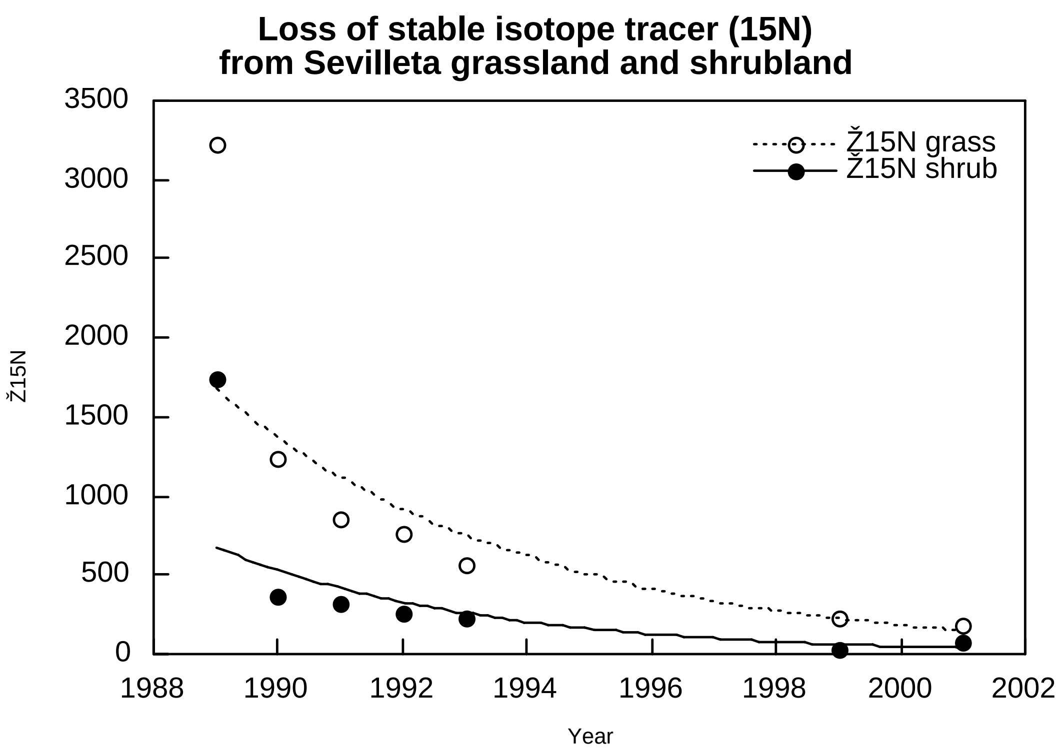


Figure 14. Changes in delta 15-nitrogen (∂ 15N) with time in Sevilleta grassland and shrubland. Values are reported as #^{15}N atoms/#^{15}N atoms + #^{14}N atoms per sample.

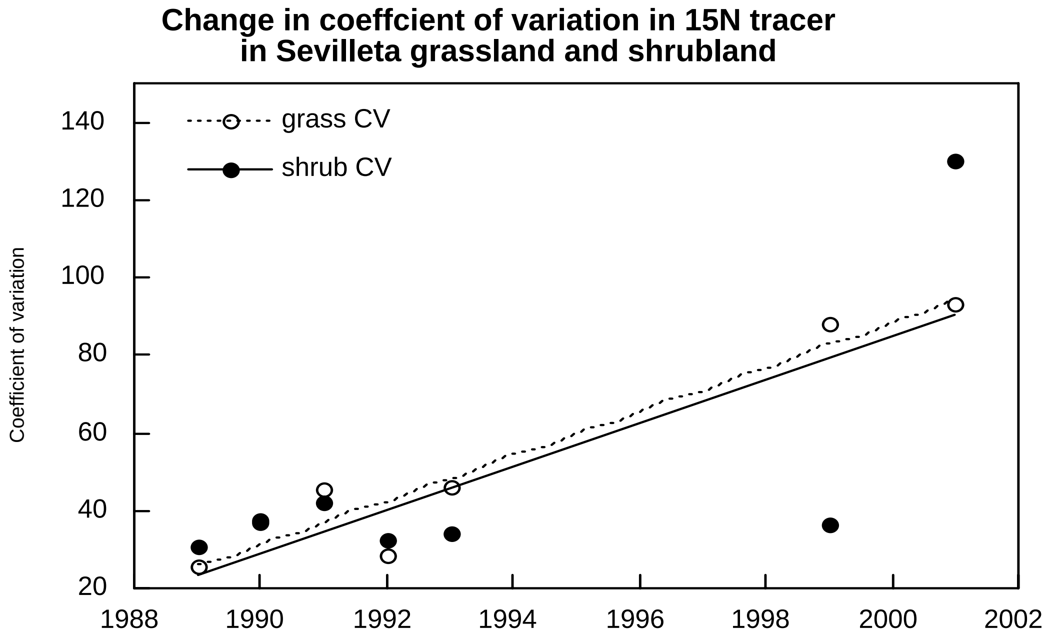


Figure 15. Coefficient of variation (CV) in the stable isotope tracer ^{15}N over an eleven-year period.

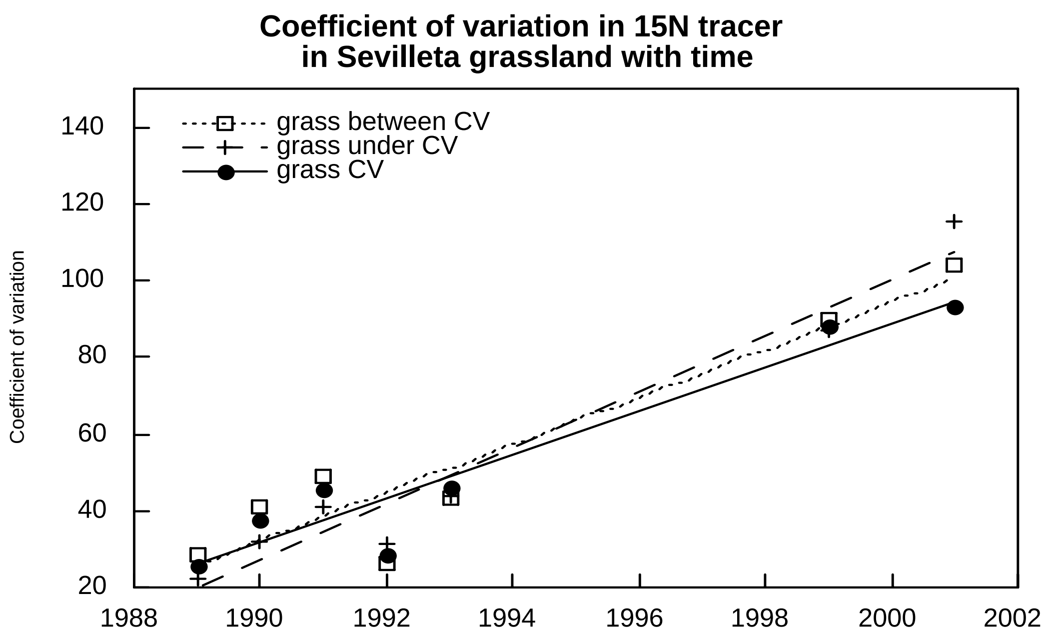


Figure. 16. Changes in the coefficient of variation (CV) in the stable isotope tracer, ^{15}N, under and beneath grass plants at the Sevilleta NWR.

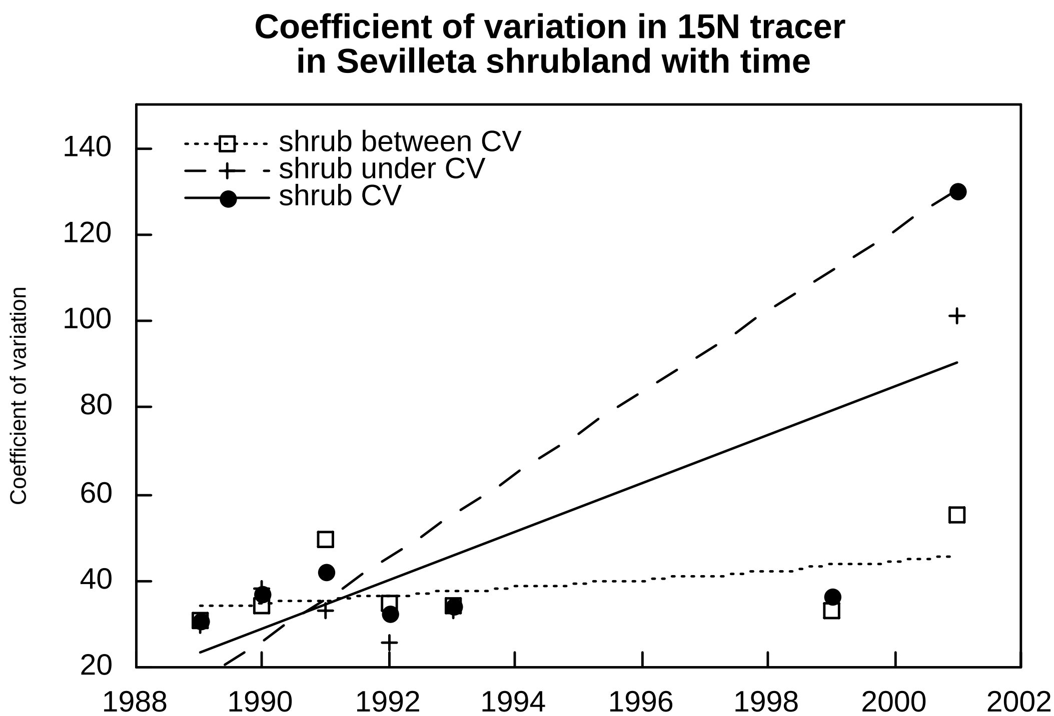


Figure. 17. Changes in the coefficient of variation (CV) in the stable isotope tracer, ^{15}N, under and beneath creosotebush plants at the Sevilleta NWR.

Vegetation studies: Plant communities and ecotones. Sevilleta LTER activities this past year have focused on two aspects of the Sevilleta field site as a biome transition zone (BTZ): characterizing the nature of the Sevilleta as BTZ on a regional scale and detecting the BTZ vegetation boundaries at local scales across the Sevilleta landscape. With respect to the former, a latitudinal floristic analysis was conducted using four plot data sets that range from the Sevilleta in the north to Big Bend National Park/ Sierra del Carmen Protected area to the south in Mexico. First, the distribution of each species in the dataset was classified with respect to biome type (Chihuahuan Desert Short Grass Steppe, Rocky Mountain or Great Basin, etc.). Then, an index of Chihuahuan Desert affinity was computed for 590 plots distributed across the latitudinal gradient. The plots were dominated by black grama, blue grama or creosotebush. The results suggest that, while the Sevilleta would still be considered predominantly “Chihuahuan” in character, it is much less so than sites to the south (Figure 18). In fact, there is a significant increase in Chihuahuan species within 100 km to the south, suggesting that the Sevilleta is definitely within a transition zone from the Chihuahuan Desert to the south and the Short Grass Steppe and Great Basin biomes to the north. Future work will extend the analysis northward to detect the shift to predominantly cool-temperate species and to put the shifts in the context of regional climatic patterns.

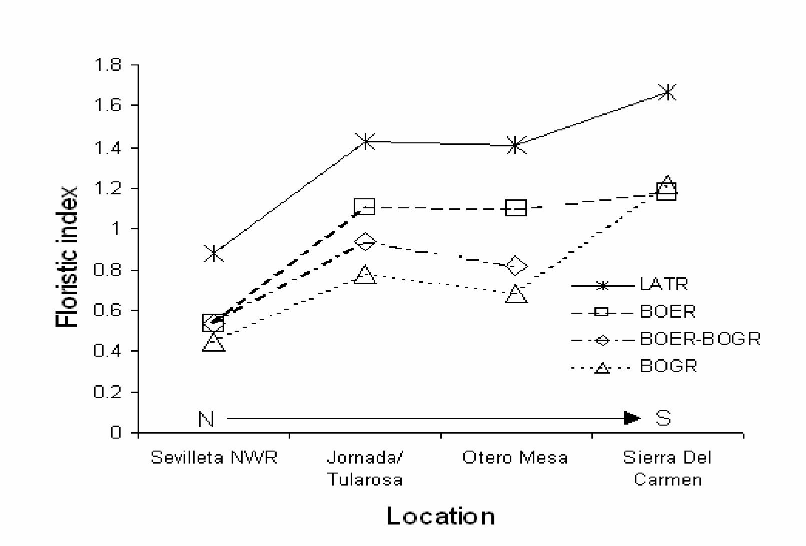


Figure 18. Plot of the floristic index of Chihuahuan Desert affinity versus site, stratified by alliance. The Sevilleta NWR is at the northern end of the latitudinal gradient; the Sierra del Carmen at the southern end. LATR = *Larrea tridentata,* BOER = *Bouteloua eriopoda,* and BOGR = *Bouteloua gracilis.*

At the local scale at Sevilleta, we established three, 6-km long parallel transects across the McKenzie Flat landscape during the summer of 2001 and sampled vegetation composition and abundance using contiguous 10 x 10 m quadrats (1,800 total quadrats). We have used these segmented belt transects to spatially detect BTZ boundaries and to get a sense of the relative abundance of transitional sites among our three main dominants (Figure 19). During the summer of 2002 we established a set of permanent repeat photography stations along the transects with emphasis on detecting creosotebush encroachment or dieoff. In addition, to detect other boundary shifts, we will be establishing fine sale sampling across transition zones as generated from our boundary analysis at the 10 x 10 m scale.

Recently, Esteban Muldavin has become the lead P.I. for NPP studies on the Sevilleta. With this fall's sampling the Sevilleta will have completed its fourth year of NPP sampling using non-destructive repeat quadrat sampling that is coordinated with the small mammal and arthropod sampling at three core sites. The estimation of standing biomass is based on regressions between measured volumes on the quadrats and equivalent biomass/volume samples from off the sample grids. Regressions have been calculated by species, season and year, and results indicate that destructive sampling for most species will no longer be required. However, given the importance of the three main dominants to our hypotheses on BTZs, we will continue to harvest black grama, blue grama, and creosotebush in 2002 to ensure maximum precision in production estimates. In the coming year we plan to consolidate the regressions and re-evaluate the need for future destructive sampling.

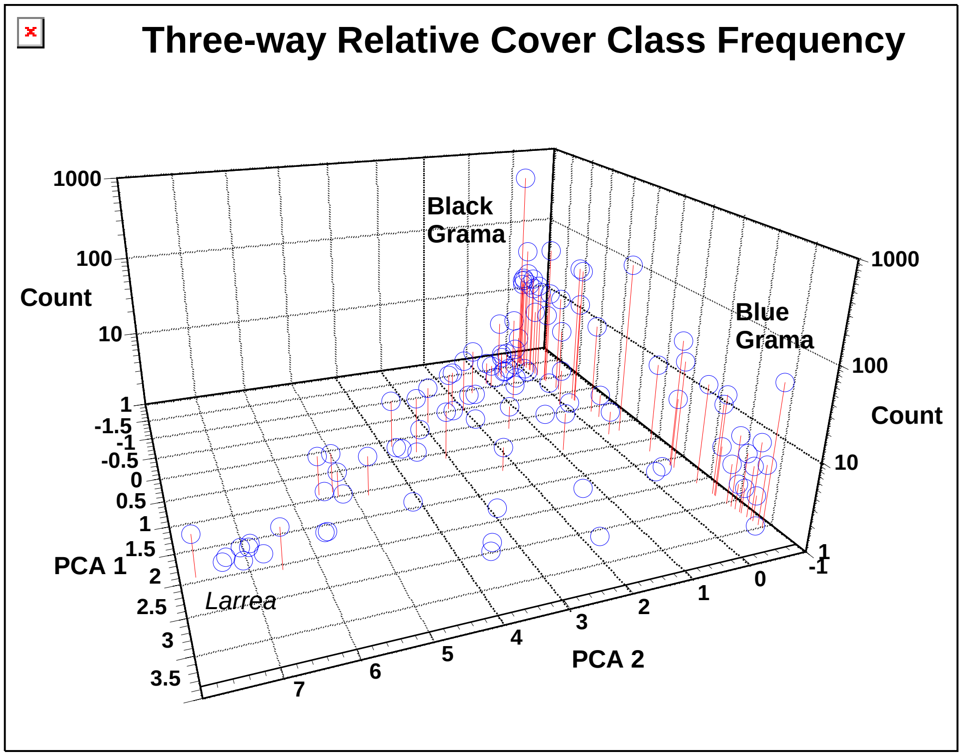


Figure 19. The distribution of 10 x 10 m quadrats by relative composition of blue grama, black grama and creosotebush (*Larrea)* along all three McKenzie Flat transects.

Extrapolation of information across spatial and temporal scales: Co-PI Peters has collaborated with a number of researchers from the JRN LTER as well as other LTER and non-LTER sites in a synthesis effort that is directly related to our new focus on scaling patch and ecotone dynamics to the landscape. Peters and several co-organizers convened three workshops at the LTER All Scientists meeting in August 2000 that dealt with the problem of extrapolating information across spatial scales. These workshops were followed by a synthesis workshop held at the SEV field station in March 2001. At that time, three working groups were formed: (1) carbon inventory and dynamics, including water, (2) invasive plants and changes in species and functional group geographic distributions, and (3) animal interactions with their environment. Two major conclusions were drawn from these groups. First, although extrapolation of information across scales has been an important topic in ecology, we still lack an organizing framework that provides an objective way to decide which scaling approach to use, and states the strengths, limitations, assumptions, and consequences of each approach. Second, scaling problems are very similar among different disciplines (animals, plants, soils), expertise (theoreticians, modelers, experimentalists), and perspectives (top-down, bottom-up). In 2001-2002, this group continued to address these scaling issues with the overall goal of developing a synthetic problem-solving approach for extrapolating information from fine to coarse scales. To meet this goal, we organized two symposia at major annual meetings (International Association for Landscape Ecology, Ecological

Society of America) that synthesized our findings to date. We are now completing five manuscripts to be submitted to a journal as a Special Feature within the next six months.

Patch characterization: We expanded our patch characterization and mapping studies in 2002 to include patches of a variety of sizes that are dominated or co-dominated by blue grama or black grama. Under Peters' direction, large patches of blue grama and black grama were located using aerial photos and satellite imagery. In the summer of 2001, four large patches of blue grama were located, flagged, and geo-referenced. In 2002, an additional three large blue grama patches were located and set up for sampling. Because each large blue grama patch borders large patches of black grama, this design included large areas dominated by black grama to the north and south of each blue grama patch. The north and south ecotones between blue grama and black grama were distinguished separately since observations suggest that different factors may control their dynamics, even within the same blue grama patch. Eight 150 m-long transects were located that traversed either the north or south ecotone for a total of eight transects per patch. Fifty meters of each transect was located within the blue grama-dominated patch and the remaining 100 m traversed the transition zone dominated by both blue grama and black grama, and continued into the black grama dominated area. Percent cover estimates by species were obtained at regular intervals along each transect using 50 cm x 50 cm quadrats and modified Daubenmire cover classes. A Total Position Station was used to obtain micro-elevation measurements and a GPS unit was used to geo-reference the center of each quadrat. Soil samples were collected along four randomly selected transects. Samples were collected by taking a soil core under a plant and in an adjacent interspace at 5 to 10 m intervals. The interspace area and basal area of each plant were measured where soils were collected. Soil core diameter varied depending on the depth interval of the sample to ensure that an optimum amount of soil was collected for sampling, yet to minimize soil disturbance (0-1 cm depth x 10 cm diameter core; 1-5 cm depth x 5 cm diameter core; 5-20 cm depth x 3.8 cm diameter core). Soil samples will be processed for particle size distribution this fall. This patch characterization study will allow us to examine the relationship between species dominance and physical features (soil texture and elevation as a surrogate for soil water) to test the hypothesis that some ecotones are stationary and controlled by soil water availability whereas other ecotones are shifting through time and do not have a strong relationship with physical features of the environment.

Ecotone dynamics: Based on findings from 2000- 2001, we hypothesized that the stability of the SEV landscape through time is dependent on the spatial arrangement of creosote-resistant areas dominated by blue grama interspersed with creosote-susceptible areas dominated by black grama. Peters initiated a field study to test this hypothesis using small disturbances created along ecotones between blue grama and black grama. Five ecotones sampled as part of the patch characterization study were selected for this experiment. Each ecotone traversed an area dominated by black grama, an area co-dominated by both species, and an area dominated by blue grama. Small disturbed plots (35 cm-diameter) were created by removing either an entire plant, half of a plant, or none of a plant of the dominant grass in each area. Half of the plots had creosote seeds added to them and the other half served as controls. Small cages were constructed around each plot to minimize herbivory by rodents and rabbits. Plots were watered until the creosotebush seeds germinated. Seedling establishment and survival are being monitored through time.

In 2001-2002, Peters studied ecotone dynamics between creosotebush and blue grama or black grama using 242 isolated patches of creosotebush (Fig. 20). We found that isolated creosote patches are most frequently found in areas dominated by black grama, and rarely occur within blue grama-dominated vegetation (Fig. 21). The spatial heterogeneity in patch invasion likely represents the greater invasibility of black grama grassland to creosote, and the greater resistance of blue grama.

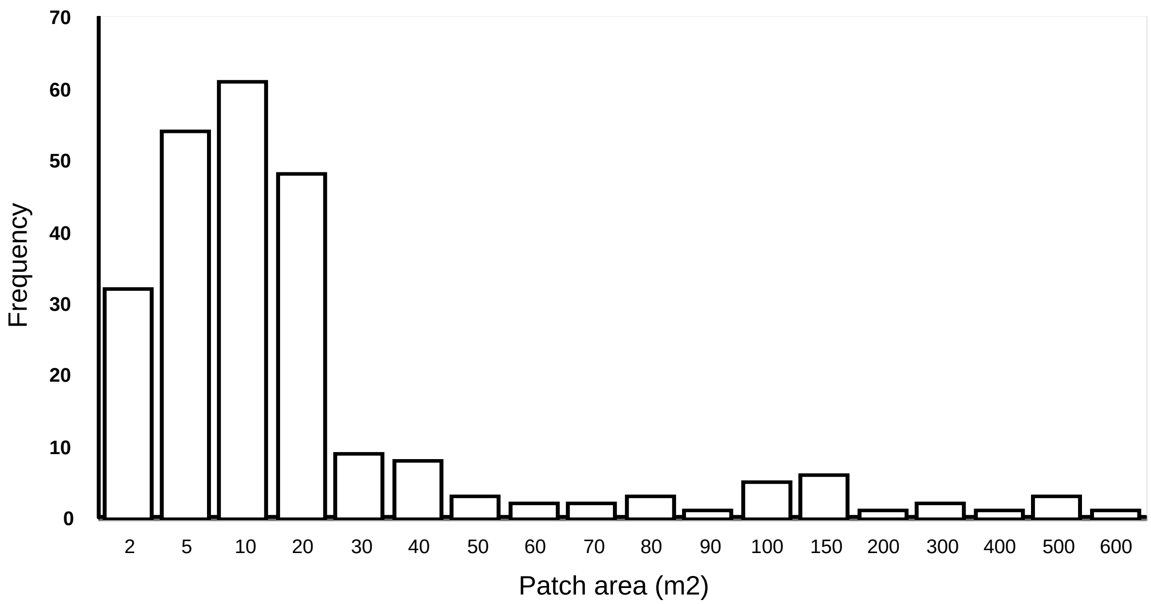


Fig. 20. Frequency distribution of the surface area of 242 creosote patches from five locations on McKenzie Flats.

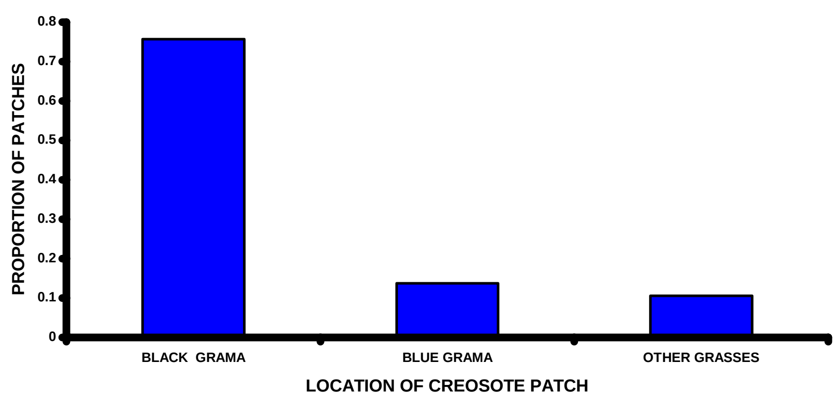


Fig. 21. Proportion of creosotebush patches located either in areas dominated by black grama, blue grama or other perennial grasses.

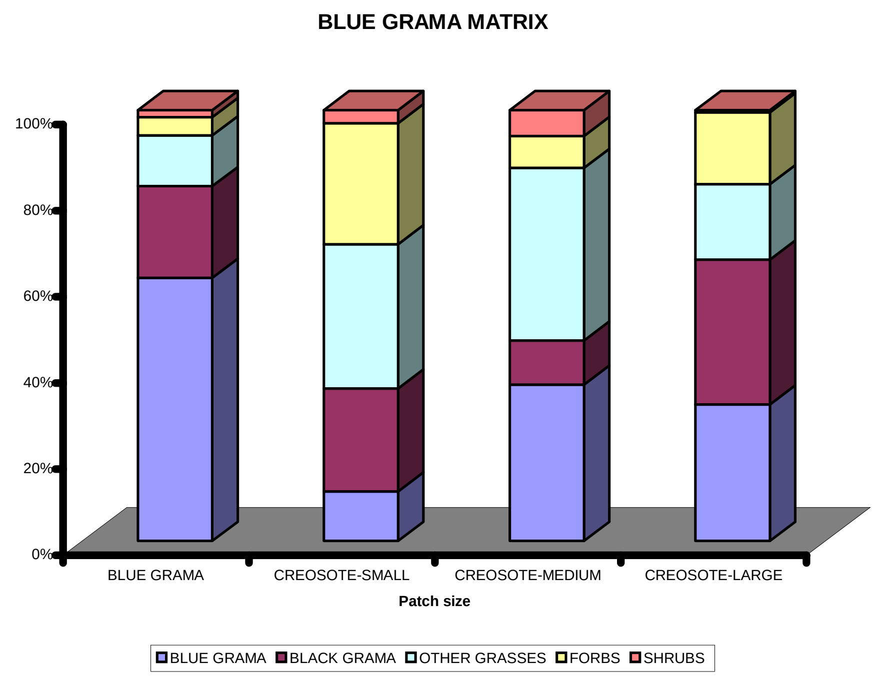
Effects of disturbances on vegetation patterns in Sevilleta ecotones: Small scale disturbances. Co-PI Deb Peters is continuing to examine the effects of small, patchy disturbances on vegetation dynamics at ecotones through experiments and simulation models. She continues to monitor the 3 m x 4 m removal plots at five sites located along a grassland-shrubland ecotone on McKenzie Flats as well as a sixth site along the foothills of Los Pinos that represents a predominately blue grama community with very small amounts of black grama and no creosotebush. The five sites have been monitored since 1995 and the sixth was added in 1998. Initial results show that removal of blue grama, black grama or creosotebush have very different effects on the remaining plant community (Peters 2000). Removal of blue grama results in invasion by perennial grasses from surrounding plots, whereas removal of black grama results in positive responses by perennial forbs on the plots. Removal of creosotebush also results in growth of plants on the plots at the time of removal, but these plants are primarily annuals. These plots will continue to be monitored annually for plant responses following removal of the dominant species. Long-term monitoring is needed to determine the species that dominates following the loss of the current dominant. Dr. Peters and her team also investigated the role of kangaroo rats in generating and maintaining plant species diversity at patch to landscape scales. They examined the contribution to species richness across spatial scales by kangaroo rat mounds located either in patches dominated by blue grama or black grama. They found that the area affected by the burrowing activity of kangaroo rats was twice as large in black grama patches compared with blue grama patches. Furthermore, dominant species on mounds in black grama patches were also abundant in off-mound areas whereas plant species on mounds in blue grama patches were not as abundant off-mound. These results indicate that the presence of mounds in blue grama patches is creating islands of plant communities that are distinct from the rest of the grassland.

In 2001-2002, we continued to monitor the long-term plant removal plots and controls for species abundance. We are preparing a manuscript for submission to a journal that describes kangaroo rat mound effects on local and landscape diversity of plants.

Vegetation patch characterization: Sevilleta LTER researchers (Co-PI Deb Peters et al.) are characterizing patches at the Sevilleta using field studies and mapping. Our initial characterization involved comparing plant species composition between blue grama- and black grama-dominated patches. We hypothesized that subordinate species at this biome transition zone would be associated with plant communities from the adjacent biomes. The alternative hypotheses are that each species is either associated independently with different patch types or distributed randomly. We tested these hypotheses by conducting spatially-explicit sampling of blue grama and black grama dominated patches. We found that most species were associated with one of the two patch types. Of the 52 species found, 16 were significantly associated with blue grama patches and 12 were associated with black grama patches. However, these subordinate species found within the different patches were not characteristic of the shortgrass steppe or Chihuahuan desert biome, respectively. Thus, patch types have characteristic life form and species composition, but patches do not represent the adjacent biomes in these features. Species respond independently to changes in environmental factors and not as plant communities.

We recently began mapping patches of dominant species located throughout the McKenzie Flats. In March (2001), we mapped > 250 patches of creosotebush in 3 belt transects near Five Points. Each patch was geo-referenced, the number of shrubs was counted, and the perimeter was outlined and mapped using the GPS unit. We also characterized the vegetation inside and outside each patch (Peters 2002). We found that small creosotebush patches had the highest cover of forbs and the lowest cover of blue grama or black grama regardless of the background matrix where the shrub patch was found (Fig. 22). Large patches were more similar to the matrix vegetation than to small patches. In 2001-2002, we expanded our sampling to include blue grama and black grama patches across a range of sizes from 1 to 70 plants per patch. Individual patches of blue grama or black grama were located along the eight transects within each large blue grama patch (Findings: Patch characterization). Patch size was measured and number of plants was counted within each patch. Each patch was marked with a nail and a flag, and geo-referenced. These creosotebush, blue grama, and black grama patches located within large patches dominated by one of the other two species will be available for use by other investigators working on different aspects of the patch size.

Synthesis using simulation modeling: Sevilleta LTER researchers are using simulation modeling to evaluate long-term effects of climate, small disturbances and soil texture on species dominance and plant community composition. The ECOTONE individual based model simulates the size and age of each plant on a small plot through time at an annual time step. ECOTONE contains a similar formulation as found in forest gap models, including the mortality routines. We conducted simulation analyses of the importance of soil texture to patterns in species dominance and composition under current climatic conditions and under a directional change in climate. Blue grama and black grama co-dominated sandy loam soils and black grama and creosotebush co-dominated loamy sand soils under current climatic conditions. These results are comparable to observed patterns on the McKenzie Flats. Under a directional change in climate that increased summer precipitation and temperature, black grama clearly dominated sandy loam soils and increased in importance on loamy sand soils. These results suggest that an increase in summer precipitation could alter the species dominance patterns at the SEV with an increase in dominance by black grama. We also conducted simulation model analyses of the effects of disturbance frequency on dominance by blue grama, black grama or creosotebush. We found that dominance by blue grama decreases and dominance by black grama increases as disturbance frequency increases; creosotebush was unaffected over the range of disturbance frequencies investigated. These simulation results complement previous field studies showing that black grama responds positively to the presence of kangaroo rat mounds whereas blue grama is negatively affected.



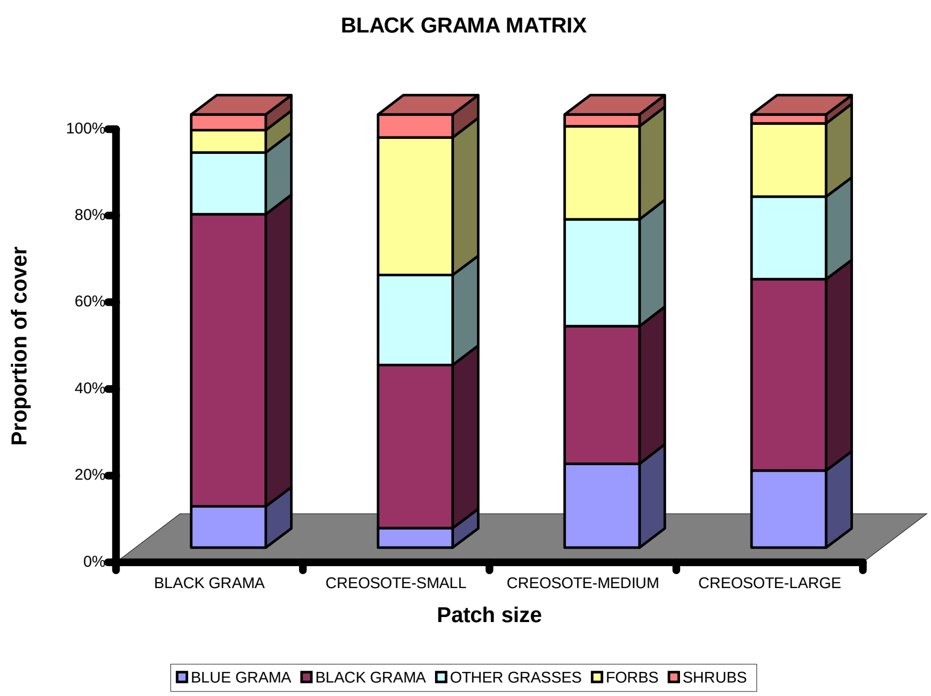


Fig. 22. Proportion of vegetative cover by blue grama, black grama, and three species-groups for three sizes of creosotebush patches located in matrix areas dominated by either blue grama grass (top) or black grama grass (bottom).

In 2001-2002, we have been thoroughly testing the capability of ECOTONE to simulate grasslands and shrublands in arid and semiarid regions (Peters). We are improving the efficiency of the code to allow large landscape units (> 1000 m^2) containing multiple patch types and sizes to be simulated. Given the small plot size (< 2 m^2), increasing code and input/output efficiency has been a major focus. We also modified ECOTONE to run under the Windows operating system instead of UNIX. This change will increase the accessibility of the model to a larger group of users, and will allow us to take advantage of the broad array of user-friendly applications available on PCs. We are investigating alternative soil water models that will allow us to redistribute water horizontally with patch and landscape position as well as vertically with depth. We are designing a patch and landscape scale spatial version of the model to be used for the complicated landscapes at the SEV. We also started on a meta-modeling approach that will allow us to simulate multiple, large landscape units within the Sevilleta. This modeling effort is a collaboration with the JRN LTER and USDA ARS, Jornada Experimental Range.

Vegetation transect studies and ecotone patterns: Ecological transition zones are believed to be unique in their ability to shed light on the organization of populations and communities. Co-PI Larry Li studied vegetation dynamics in the Great Plains short-grass steppe and Chihuahuan desert grassland ecotone in New Mexico, USA using long-term, high resolution transect studies of the Sevilleta LTER Program. Li focused on spatial patterns and examined this in several ways: patch size distribution, spatial autocorrelation analysis, and fractal scaling. These methods were used to examine the effect of distributional limits on dynamics of the dominant species and the detection of an emergent scaling property. Li and his graduate students found the following:
(1) no characteristic spatial resolution (quadrat size), but rather a fractal structure of spatial variation in abundance and (2) consistency of the pattern in time when species were closer to their distributional limit. In this, they were able to detect a robust power law behaviour (the emergent property), indicating strong spatial organization via anti-persistence. Graduate student Xuefei Wang finished his master's thesis on the same data as well, *Temporal and spatial structures of black and blue gramas: statistical analysis of biotic and abiotic interactions from Sevilleta vegetation transect data* (2001).

Vegetation map of ecotone study area. A vegetation map of the interface of the Chihuahuan Desert grassland/shrublands and Great Plains shortgrass steppe at the SNWR is under construction. The map is based on spectral mixture analysis (SMA) of low altitude AVIRIS data (3.2 meter pixels) collected 10-20-99 and 10-21-99 and covering a large portion of the study area. The SMA endmembers or spectral signatures of ground components were derived from the AVIRIS imagery using a manual endmember selection method and simulated annealing algorithms. Over 40 AVIRIS images at 3.2-m resolution have been processed using spectral mixture analysis. All images have been registered to a geometrically-stable 4-m IKONOS image. We are in the process of rescaling the georegistered data for merging flightlines, thereby producing a geometrically correct rendition of vegetation distribution in the study area. The map will be completed and ready for field validation by the end of 2002.

Scaling NPP and Foliar Nitrogen Concentration to the Landscape: Graduate student Bryan J. Brandel has begun his dissertation study on resource availability and utilization within vegetation patches on the Sevilleta's McKenzie Flats study area. Resource availability varies spatially and is potentially related to patch size. However, little research has been performed on nutrient and resource levels as a function of patch size within biome transition zones in the Sevilleta LTER. Brandel will collect field samples from patches of various sizes in order to identify the influence of patch size on net primary production and foliar nitrogen concentration in creosotebush (*Larrea tridentata*). NPP will be determined based on volumetric measurements and allometric relationships between volume and biomass. Foliage samples will be collected for lab analysis to determine foliar nitrogen concentrations. Based on the results of the patch scale investigation, Brandel will extrapolate the data across the landscape using remote sensing data to determine the spatial variation of NPP and foliar N concentrations in the Chihuahuan Desert/Great Plains Shortgrass Steppe transition zone in the Sevilleta. By utilizing fieldwork as a foundation for novel remote sensing analysis, he will make the important transition from patch scale properties to broader landscape function. Extrapolation to the landscape will illustrate the association of these ecosystem properties with the ecotonal structure, and will help us understand whether knowledge of spatially explicit processes is necessary for studies of regional biogeochemical cycles.

Vegetation responses to climate change: Rainout Shelter Experiments. This project addresses the response of the ecotone to prolonged drought. During the past year, Co-PIs Drs. Eric Small and Will Pockman have completed construction of rainout shelters in grassland, shrubland and mixed grass-shrub vegetation at 5 points. This includes construction of the shelters themselves, as well as initiating growth measurements on the shrubs (grasses will be measured at the end of their growing season) and installing vertical profiles of soil moisture probes (Time Domain Reflectometry, Thermocouple Psychrometers and Heat Dissipation probes) under plant (grass and/or shrub) canopy and interspace. These sensors (228 Thermocouple psychrometers, 189 TDR probes, 102 heat dissipation sensors) are presently being measured automatically by dataloggers at the site. Our intensive measurements include the monitoring of soil moisture, ET, and other aspects of the surface water and energy budgets. In addition, we completed 9 'reference storms' at the ecotone plots to assess the coupled plant-water response to summertime rainfall. A 15 mm artificial rainfall event was added to each plot, followed by ~10 days of intensive measurements. Finally, we began a detailed spatial analysis of the patterns of canopy and interspace in grassland and shrubland environments. Analysis of these datasets has yielded two submitted manuscripts and one in preparation. Complementary water addition manipulations are planned but these are beyond the financial means of the Sevilleta and are dependent upon obtaining sufficient funding to carry out this part of the manipulation in an effective manner (proposal pending with DOE NIGEC). Juliana Medeiros, a master's student in Pockman's lab, has begun a study of the physiological differences between size classes of *Larrea tridentata* in the ecotone. She is comparing patterns of gas exchange, water relations, hydraulic conductance and growth among two size classes of creosotebush.

The rainout shelter treatments have just begun, so no definitive results are available from the manipulative component of the experiment. Mixed vegetation soil moisture probes have been operating for one year during construction of the remaining experimental plots. These data will be used to develop a publication in the next 3 months describing the patterns of differential infiltration that are observed under grass and shrub canopies relative to infiltration under interspace. Intensive measurements of plant responses following a natural storm will be used to describe the current state of grass and shrub responses to a soil moisture pulse.

Drought Effects on Soil Nitrogen Resources. The recent drought in central New Mexico has provided an opportunity to replicate a study from the drought years of 1989 and 1996, testing the effects of drought on soil nitrogen dynamics. Soils from the LTER's "Fertilizer Plots" on McKenzie Flats were initially sampled in the spring and again in the fall of 1989 (and subsequently through the LTER studies) for field-extractable nitrogen (N) and for N mineralization potentials (incubations at near-optimal soil miosture and 20°C). These forms of soil N in the first collections were higher than in later collections, until 1996 when soil N values increased again. Soils were also collected from the Bernalillo Watershed near Placitas and from a site west of the City of Albuquerque ("West Mesa") in the fall of 1995 and at different times through 1996, and continue through this date. The same soil N analyses of soils at the Bernalillo Watershed and the West Mesa rose in late 1995 through the spring of 1996, similar to the pattern shown for soils at Sevilleta's McKenzie Flats. We attributed the increase in soil N to the drought, while the anticipated response to a prescribed fire produced no change from soils at control plots. Thus, drought had a greater impact on soil N availability than did management with prescribed fire. The importance of drought on soil N resources is strongly suggested by two drought periods at the Sevilleta (1989 and 1996) and by the 1996 drought at the Bernalillo Watershed. The current (2000-present) drought conditions pose the opportunity to augment existing data on the effect of drought periods on soil N resources, and additional samples are being collected to further test these hypotheses.

Creosotebush Freezing Studies: Analyses of freezing induced xylem cavitation showed that creosote bush at the Sevilleta is more resistant to freezing than a population studied in southern Arizona. However, the difference in freezing tolerance was smaller than the difference in actual minimum temperatures at these sites. As a result, we observed greater xylem embolism levels in the Sevilleta population than were observed in southern Arizona. This suggests that the accumulation of embolized, nonfunctional xylem may compromise plant function and contribute to physiologically defining the northern limit of the species.

Dynamics of evapotranspiration (ET) in semiarid grassland and shrubland. ET is a major component of the water cycle in semiarid environments, equal to precipitation with measurement error. However, few long-term records of ET exist. We have measured and analyzed two summers of data from ecosystems typical of desert valley environments, grassland and shrubland. We have four primary results:

(1) Intense temporal variability of ET and evaporative fraction (EF): High values of ET and EF are observed directly following rainfall events in grassland and shrubland (ET ~ 4 mm/day; EF ~ 0.7). At both locations, ET and EF return to low values (ET ~ 0.5 mm/day; EF ~ 0.1) within only a few days.

(2) Drydown is faster in shrubland: The drydown following rainfall is roughly exponential with shorter time constants (τ) at the shrubland (τ_{EF} = 1.4 days) than at the grassland (τ_{EF} = 2.6 days), for both soil moisture and EF or ET.

(3) Linear relationship between EF and surface soil moisture: EF and ET vary linearly with soil moisture (τ measured from 0-5 cm (r^2 ~ 0.8 for both EF and ET at either site).

(4) ET is similar in grassland and shrubland, however, this does not mean that evaporation and transpiration are identical. Instead, evaporation is expected to be much higher in shrubland due to extensive bare soil (~70%).

Implications are as follows. First, shallow soil moisture (0-5 cm) is the key control of ET in these environments, suggesting a large bare soil evaporation component. Second, temporal variability of ET is substantial and must be represented by models of land-atmosphere interactions. Third, vegetation type does not noticeably influence the total flux of water back to the atmosphere, although it influences coupled plant-water response to monsoon rainfall events. Shrubs (e.g., creosotebush) and grasses (e.g., black grama) have different rooting patterns, arrangements of above-ground structure, and photosynthetic pathway (C3 vs C4). Therefore, their response to rainfall events is believed to differ, yielding competitive advantages that can lead to changes in ecosystem composition. Shirley Kurc, Ph.D. student at the University of Colorado, made significant progress on her thesis, *Coupled water and energy balance of desert grassland and shrubland ecosystems*. In the past year, she collected and analyzed two years of surface energy balance data from grassland and shrubland in the Sevilleta. Results are described in a paper submitted to Water Resources Research. Salient results include:

(1) Infiltration is shallow; soil beneath plant canopies is wetter than beneath interspaces: The soil at depths greater than 45 cm is usually dry, only wetting slightly (to –2 MPa) after a multi-day rainfall event in August 2001. The soil tends to be wetter beneath grass than shrub canopies, both following monsoon rainfall and during the winter.

(2) Grass response to a 15 mm rainfall event is more dramatic than for shrubs: Grass plant water potential increased substantially (to –1.5 MPa) following a 15 mm rainfall event (September, 2001) whereas shrub plant water potential increased only slightly. The transpiration responses, normalized to pre-storm values, were similar: grass transpiration increased by a factor of five whereas shrub transpiration did not even double.

(3) C assimilation-ψ_{soil} relationship for grass and shrub is similar: The measured paired values of carbon assimilation and soil water potential fall along the same curve for grasses and shrubs. Greater assimilation by grass is the result of wetter soil beneath these plants.

The key implication is that the primary control on the amount of carbon fixed as a result of the observed storm was the pattern of infiltration. The soil beneath grass was wetter, so this plant type fixed more carbon and lost more water.

Energy-Water Balance studies in Sevilleta piñon-juniper woodlands. Graduate student Andrew Kerkhoff's dissertation, entitled '*On the distribution and dynamics of vegetation: From ecohydrology to life history*' focused in part on the piñon-juniper woodland site in the Los Pinos Mountains. In particular, he investigated topographically mediated water-balance constraints on the distribution of woodland tree canopies. Additionally, he performed the first ecological evaluation of an analytical water-balance model that is very well regarded by hydrologists and is poised to form the theoretical basis of the emerging discipline of ecohydrology. Because BTZs in the arid southwest are thought to be largely determined by site water-balance, his research is very pertinent to the Sevilleta's mission. He successfully defended his dissertation and graduated in May, 2002.

Surprisingly, variation in water-balance parameters could only explain 40% of the variation in tree canopy cover in the Los Pinos site in a regression tree analysis. However, residual variation in tree cover was highly correlated with tree canopy cover in the neighborhood of a particular sample site. This indicates that localized, historical processes such as seed dispersal and facilitation may have a large effect on the distribution of trees in semiarid woodlands. This study, '*Biophysical variation and the contingencies of tree canopy density in semiarid woodlands*,' coauthored with Scott Martens, Bruce Milne, and Greg Shore, is in review for publication in Ecosystems.

Kerkhoff also carefully examined the assumptions underlying an analytical water-balance model developed by Peter Eagleson, then tested model predictions using biophysical parameters drawn in part from the Los Pinos woodland site. He found that ecological application of the model was dependent on unrealistic assumptions about the dynamics of vegetation. Further, he found that model predictions were impaired by an inadequate treatment of water-limited transpiration. His review and test of this model, '*Inspiration without transpiration: testing Eagleson's ecological optimality hypotheses*,' with coauthors Scott Martens and Bruce Milne, has been submitted to Functional Ecology. Kerkhoff is currently a postdoctoral research associate in the Department of Ecology and Evolutionary Biology at the University of Arizona.

Hydraulic constraints on the gas exchange capacity of plants: Graduate student Juliana Medeiros has begun her studies on the distribution of woody shrubs in warm deserts, to determine to what extent they are limited by their ability to access water and maintain a positive carbon balance under frequent conditions of low soil water potentials. Plants in water-limited environments face frequent drought and an age-old dilemma: opening stomates to access carbon dioxide for photosynthesis necessitates the flow of water down a concentration gradient, into the atmosphere. As a consequence, desert plants have been shown to have, in general, higher water use efficiency than inhabitants of more mesic environments. Recently, however, studies have shown that juveniles of woody desert shrub species such as *Larrea tridentata* exhibit lower water use efficiency than adults, despite the fact that they generally experience lower soil water potentials. The physiological mechanism by which this is accomplished remains unclear, however. The extent to which a plant can adopt a strategy of low water use under conditions of water limitation is determined by characteristics of the soil and the plant's ability to withstand low values of xylem water potential. This is because both are possible points of embolism, which can cause the cessation of water transport through the plant if extensive.

Field experiments will investigate the possibility that juveniles of *Larrea tridentata* adopt a strategy of low water use efficiency in order to maximize their growth and make it as quickly as possible through this vulnerable stage. The growth and water use characteristics of the study plants will be correlated with hydraulics characteristics of the two size classes. Specifically, do different size classes grow and use water differently, and if they do, what differences are there in how closely they push the limits of catastrophic xylem failure? A mathematical model will be tested to see whether catastrophic embolism occurs in the xylem or the soil for the two size classes of this population. Excavations of juveniles and adults will be used to characterize the root systems of individuals growing under the particular combinations of water and soil characteristics of the site.

Data were collected at four times during summer 2002. May 31 predawn and midday plant water potentials were taken for 5 plants of each size. June 14 and 15 diurnal gas exchange and predawn plant water potentials were measured for 5 of each size. In addition to the original 100 plants, 100 more plants were tagged at this time. June 26-29 hydraulic conductance of roots was measured for 5 of each size, and growth measurements were taken for 15 plants of each size. August 11-22 diurnal gas exchange, predawn and midday plant water potential and hydraulic conductance of roots and shoots were measured for 10 plants of each size. August 22 growth measurements were taken for 15 plants of each size. Soil water potential measurements were collected for two periods, from May 15 to June 30, and from August 6 to 18.

Analysis of results from May and June sampling periods indicated that sample sizes for gas exchange and hydraulic conductance should be increased to 10 per size to improve statistical power. In addition, a new method for measuring hydraulic conductance in stems of small plants was also needed. Preliminary statistical analyses suggest that there was no significant difference in predawn and midday plant water potentials or hydraulic conductance of roots for small and large plants during the summer of 2002. There was, however, a significant difference between percent loss of hydraulic conductance of large roots and shoots, with roots having a lower percent loss of conductance. There was also a significant difference in the diurnal course of gas exchange for small and large plants, with small plants having a different pattern of gas exchange throughout the day as well as higher values of photosynthesis and transpiration. Statistical analysis of growth measurements is forthcoming.

Gene Flow in Fragmented Plant Populations at the Landscape Level: Accurately characterizing the impact of habitat fragmentation has become the current paradigm in conservation biology as anthropogenic influences continue to divide populations and habitats. It has been shown that selection pressures associated with habitat fragmentation can cause local plant populations to: (i) decline in size, (ii) go extinct, (iii) become locally adapted, or (iv) increase in size with increased edge habitat availability. Most of these effects, however, can be ameliorated by gene flow. It is therefore particularly important in the examination of fragmented populations of plants to consider the factors that affect gene flow. These include ecological and demographic parameters, such as population size, distance between populations, and the strong interspecific mutualism of plants and their pollinators.

The absence of anthropogenic influences, such as grazing and urban sprawl, make the Sevilleta National Wildlife Refuge (SNWR) a unique setting for experimental manipulations of populations and habitats. Graduate student Jerusha Reynolds began her field work on plant gene flow at the Sevilleta during 2002. Using experimental populations composed of wild radish, *Raphanus sativus* L. (Brassicaceae), she established a 2500 m linear transect at the SNWR upon which the centers of eight genetically unique populations were placed at zero, 23, 70, 164, 351, 726, 1476, and 2500 meters; i.e. the populations were spaced at progressively increasing distances. There were three population size treatments (in terms of area; population density was equal across all treatments): 11.25, 22.5, and 45 m^2 representing populations of 20, 40, and 70 individuals, respectively. For each treatment, radishes raised in the greenhouse were placed in the field in pots, exposed to pollinators for five days (during which time potential pollinators were identified and censused), and returned to the greenhouse where the fruits are currently maturing. The same transect was used for each treatment. To ameliorate the effect of seasonal timing on gene flow, two replicates with different orders of treatments were performed. Once fruits have matured, paternity of a sub-sample of seeds will be assessed to determine the range and magnitude of gene flow. Finally, these data will be used to develop a spatially explicit model of population viability that incorporates the essential contribution of the plant-pollinator mutualism.

Animal studies: Arthropods. During 2001-2002, we continued studies on arthropods, including surface-active arthropod assemblages (pitfall trap studies) and grasshopper assemblages (belt transects). Analyses of surface-active arthropods have focused on compositional differences and spatial patterns of taxa across the Sevilleta ecotones; species with general and microhabitat preferences have been identified, and new studies concerning the environmental factors that limit their distributions have been initiated. In addition, Parmenter and his REU student, Nathan Bohls, conducted a study that examined the arthropod communities on patches of black grama grass across the ecotone of desert scrub to grassland. This study was comparable to a study in 2000 that examined shrub-dwelling arthropods on creosotebush across this same ecotone. In the current study and based on our preliminary results, we also found the patterns observed were consistent with Island Biogeographic Theory, with “island size” (sizes of black grama grass patches) being positively correlated to numbers of grass-dwelling arthropod species, and “island distance from mainland” (the distance of isolated grass patches from “pure” black grama grassland) being negatively correlated with arthropod species richness.

In addition, we continued the monitoring program for pollinators (native bees), conducted by LTER field technician Karen Wetherill. The study involves trapping bees using Moericke traps on a monthly basis. During the first two years of this study, we have developed a voucher collection of Apoidea and are identifying all bees present to the species level. These data will be compared with the data collected from the plant phenology study that began in February of 2000 to look at community structure of the flowering plant populations and their pollinators. There are three study sites, creosotebush shrubland, black grama grassland, and blue grama grassland. Ms. Wetherill will start her Ph.D. work with the Sevilleta LTER in 2003.

Rodents, rabbits and coyotes. During 2001-2002, LTER Co-PIs Bob Parmenter and Terry Yates continued studies on rodents, rabbits, and coyotes. Data from the rodent studies were incorporated into analyses testing the "Trophic Cascade Hypothesis" to ascertain the drivers of rodent population increases and crashes, and to predict outbreaks of zoonotic diseases (hantavirus and plague). Drs. Yates and Parmenter incorporated satellite AVHRR NDVI values for the McKenzie Flats region of the Sevilleta, ground-truthed percentage cover data of vegetation in the same area, climatological data, and the rodent data to develop a predictive model for the trophic cascade and eventual risk of zoonotic disease. These results will be published in the November, 2002, issue of BioScience. In addition, graduate student Michael Friggins is finishing his thesis, entitled *The role of climate and net primary production as drivers of rodent population dynamics*. This study has shown that precipitation and NPP influences on rodent populations are both species-specific and site-specific, but that patterns are discernible. We anticipate 2-3 manuscripts to be submitted by December, 2002, from his thesis.

Prairie dog studies: Graduate student Ana Davidson continued her dissertation study on *Comparative Effects of Gunnison's Prairie Dogs and Banner-Tailed Kangaroo Rats on Vegetation, Grasshoppers, and Lizards in a Semi-Arid Grassland.* Vegetation, grasshopper, and lizard data were collected around prairie dog and banner-tailed kangaroo rat mounds (hereafter, kangaroo rats) and adjacent "non-mounds," and on the prairie dog colony and off the colony where only kangaroo rats occur (kangaroo rat site). Davidson's results demonstrated that Gunnison's prairie dogs and banner-tailed kangaroo rats had significant influences on plants, grasshoppers, and lizards. However, they appeared to affect plants and animals at different scales. In general, the patterns found in plants, grasshoppers, and lizards on the colony tended to be similar to those found on the mounds. Species known to be associated with disturbance or bare soil tended to be more common on the colony and mounds (i.e., annual plants, certain arthropods, and lesser earless lizards). The kangaroo rat site tended to demonstrate similar patterns to that of the non-mound areas. Species known to be negatively associated with disturbance or associated with grasses were more common off the colony and off the mounds (i.e., perennial plants, certain arthropods, and whiptail lizards). These results indicate that the prairie dog colony and mound areas probably had a greater degree of disturbance.

Plant measurements were also collected within exclosure plots that exclude both prairie dogs and kangaroo rats (total exclosure) and only prairie dogs (pdog exclosure), respectively. Plant height and total cover (especially perennial grasses and the exotic weed *Salsola kali*) was greater in the total exclosure, lower in the prairie dog exclosure, and lowest in the control plots. The exclosure plots clearly demonstrated that clipping activities of prairie dogs and kangaroo rats reduces *S. kali* and favored grass species (e.g., *Sporobolus cryptandrus*), and the combined effect on these plants by both rodents was greater than that caused by only kangaroo rats.

Granivore Studies (Mammals, Birds, Ants). Sevilleta LTER graduate student, David Whalen, continued working on his Ph.D. dissertation, entitled, *Resource Allocation Among Granivores across a Grassland-Shrubland Ecotone*. Recent studies have demonstrated that, despite fluctuations in species composition, species diversity is often a fairly invariant and seemingly emergent property of ecosystems. The invariance of species diversity suggests that species must subdivide resources in a constant and regular manner. In other words, there must be some very fundamental rules that govern how resources are allocated among species within a community. This project is investigating the role that multi-scale vegetation and resource distribution patterns play in the allocation of resources among granivores at a grassland-shrubland ecotone. Sixteen study plots have been established among desert grassland and creosote shrubland habitats on the Sevilleta National Wildlife Refuge. At each of these locations, late summer (post-monsoon) surveys of seed-eating ant populations (primarily *Pogonomyrmex* spp.) and fall, winter, and spring surveys of granivorous birds are being conducted. These surveys, combined with ongoing rodent trapping activities within the area, are being used to make estimates of population-level energy use within the granivore community. In addition, summer and winter seed foraging experiments have been conducted at each study plot. Consumption of seeds in patches spanning several orders of magnitude (10^0 - 10^3 seeds) by ants, rodents, and birds were measured at 400 subplots. The effects of seed density and vegetation structure on seed consumption patterns are currently being assessed. Along with some additional experiments, this information is being used to examine how resources are allocated within a community that includes species spanning a range of body sizes and foraging scales. This project is scheduled for completion in Spring 2003.

Remote-sensing/GIS/GPS/System Administration for LTER 2001-2002: Current research is focused on vegetation mapping and biomass estimation from remotely sensed imagery. Co-PI Dr. Deanna Pennington has joined the Sevilleta LTER team and begun research using remote sensing data to address a number of topics.

Vegetation mapping. One hypothesis being studied at the Sevilleta is that patch boundaries in biome transition zones may change in two ways: as directional shifts that result in patch establishment and expansion into new areas, or as part of a shifting mosaic that brings about spatial and temporal variability, but not long-term changes in dominant vegetation types. Testing this hypothesis requires mapping of the spatial distribution of vegetation types and analysis of changes in boundaries through time. Pennington is investigating methods for accurately mapping vegetation boundaries through space and time using remotely sensed imagery at two scales.

At the regional scale, Pennington is distinguishing between pinyon, juniper, and grass, to map boundaries of these major transition zones. Using combinations of hyperspectral and Thematic Mapper imagery, movement in these boundaries may be mapped back to 1972 when the first TM imagery was acquired. It is possible that older Corona imagery and/or air photos could extend these boundaries back additional decades. The hypothesis is that these boundaries respond to large scale changes in climate related to approximately 60-year drought cycles (identified by co-PIs Bruce Milne and others).

These shifts in boundaries are caused by piñon and juniper mortality during extended drought periods that shifts the grass/juniper and juniper/piñon boundaries to higher elevations.

On McKenzie Flats, Pennington is using hyperspectral imagery to try to distinguish between dominant grasses (black grama, blue grama, and galleta grass). She is collaborating with the San Diego Supercomputer Center to investigate the use of new classification algorithms using support vector machines and genetic algorithms to better distinguish between vegetation types with similar spectral characteristics. This work requires the development of extensive ground truth training sets for these grass types. The fourth dominant vegetation type on the McKenzie Flats, creosotebush, may not be identified at the resolution of the hyperspectral imagery except where it is abundant. Creosotebush will be mapped using air photo analysis from the past decade. Later in the project, these data will be extended further back in time using historic photos.

Biomass estimation. An overarching hypothesis of Sevilleta research is that ecosystems change as a result of changing climate, and these changes are most easily observed in biome transition zones. It is likely that communities respond differently to climatic change. One measure of vegetation communities is overall biomass. This project uses Thematic Mapper imagery to make spatially-explicit estimates of biomass, which can then be analyzed through time, both globally and stratified by biome/plant community.

This project depends on biomass work being conducted by the LTER group. This research relates field measurements of plant cover in plots to biomass volumes. Plot estimates of biomass will be statistically related to vegetation indices from remotely sensed imagery for those locations using multiple linear regression techniques. In addition to the commonly used Normalized Difference Vegetation Index (NDVI), Pennington is investigating the development of more complex indices from hyperspectral imagery that might better relate to biomass. Once spatially-explicit estimates of biomass through time have been made, these data will be used to estimate net primary productivity by summing peak occurrences of biomass in the spring and late summer.

Data Management. SIMS: The Sevilleta Information Management System. Funds from several projects that rely on SIMS was assembled to fund a system administrator for the Sevilleta LTER. Renee Brown, an undergraduate student in computer science at UNM, was hired in January and has kept the Sevilleta UNIX and Windows NT systems secure and operational since that time.

Five HP Jornada 720 palmtop computers were purchased which will be used by the field crew to gather data. This is expected to greatly reduce the amount of time they need for data entry.

The Sevilleta LTER web page has been updated with several new project pages describing individual projects being conducted at the Sevilleta (e.g. The Role of Fire in

the Chihuahuan Desert and Shortgrass Steppe: http://sevilleta.unm.edu/research/local/plant/bootleg/).
Several of the long-term research projects' data collection and processing protocols have also been updated and placed on-line as part of project pages.

All data sets associated with long-term studies at the Sevilleta (Rodent Population, Phenology, NPP, Line-Intercept Plant Monitoring, etc.) are up-to-date and QA/QC protocols applied. These data sets will be archived and put online at the end of the calendar year 2002.

Network-Level Activities: Kristin Vanderbilt, Sevilleta LTER Information Manager, is serving on the LTER Information Manager Executive Committee. She organized the annual LTER Information Managers' meeting, which was held July 11-13, 2002 in Orlando, FL. She served as the Assistant Editor of *Databits*, the LTER IM community's newsletter, in the spring of 2002. She is currently serving as the Editor of *Databits*. She is helping to develop a mentoring web page for new LTER Information Managers, which will be hosted by the LTER Network Office.

ClimDB Participation: Sevilleta received a supplement for $8000 from NSF to hire a programmer to automate the processing of climate data such that ClimDB, the centralized LTER climate database, will be updated daily. Climate data presently require a great deal of manipulation by the climatologist, Doug Moore, in order to put it in the format that ClimDB needs to harvest it. The programmer will write scripts to enable the data processing to occur automatically. In addition, the programmer will write scripts to extract hydrological data relevant to the Sevilleta from USGS databases, and provide them to the centralized HydroDB database, which also resides at Andrews LTER.

The Sevilleta is participating in a collaboratory project between the San Diego Supercomputing Center (SDSC) and the LTER to demonstrate that ClimDB can be implemented in a web services architecture. Kristin Vanderbilt attended a planning meeting at SDSC in May 2002 during which the goals of this year-long project were defined. Initially, the current ClimDB harvesting system will be implemented as a web service and each individual LTER site will be "wrapped" as a web service. The overall objectives of this project are to have the ability to access distributed data from each LTER site and integrate it "on the fly" and deliver it to the client, rather than storing all the LTER's climate data in a single database. Sevilleta will be one of the sites used to demonstrate that web service technology can be used in the LTER Network for the development of Network Information System (NIS) modules.

EML Implementation: Sevilleta will be compliant with the network-wide objective of having all metadata converted into Ecological Metadata Language (EML) by summer 2003. Kristin Vanderbilt attended two training sessions about EML at Arizona State University this year. During these sessions a strategy was developed by which Sevilleta metadata will be converted to EML. With assistance from personnel at the LTER Network Office, Data Junction software will be used to parse some of the structured

ASCII metadata into EML. Other data will have to be converted into EML using Morpho and cutting and pasting from the original document.

Cross-site activities

Our cross-site studies include a comparison of plant species diversity and vegetation structure at three LTER sites in the US (SGS, SEV, JRN) with three arid grassland sites in Hungary. We are expanding our cross-site studies to include additional Chihuahuan desert sites (Big Bend National Park, Armendaris Ranch, Ft Bliss) and shortgrass steppe sites (Kiowa and Comanche National parks).

1. As part of our previous NSF grant, we compared patterns in plant species diversity, productivity and climate for the three LTER sites located along a north-south gradient within adjacent grassland biomes (shortgrass steppe, Chihuahuan desert) and their transition zone. We tested two hypotheses: (1) local or alpha diversity is related to climate or plant productivity, and (2) spatial heterogeneity or beta diversity and total site-scale richness are highest at the transition zone. Most measures of precipitation and moisture at the SEV were more similar to the JRN than to the SGS. Temperature increased along a north-south gradient. Perennial species richness at the local and site scales as well as spatial heterogeneity were related to a long-term aridity gradient where richness was highest at the semiarid SGS site compared with the more arid Chihuahuan desert (JRN) and biome transition sites (SEV). Richness of perennials was highest at the SGS as a result of large numbers of C_3 perennial species. Long-term data showed that local-scale richness of annuals was related to precipitation in the year of sampling. Site-level richness of annuals was similarly high at the two most arid sites, mostly as a result of C_4 annual grasses and forbs

In 2001-2002, we established a series of new experiments along this same climatic gradient. We are relating seed bank dynamics with disturbance characteristics at each site.

2. We are also 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 SEV in July 1998 following a lightning-ignited fire in Bootleg canyon. 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 vegetation responses. 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 JRN-LTER, we focused on the response of black grama and honey mesquite following fire. Combining results across sites will allow us to examine the effects of precipitation and temperature as well as grazing or exclusion on recovery of perennial grasses following fire.

In 2001-2002, we resampled the Bootleg fire plots at the SEV. We found that black grama mortality was higher than expected based on previous fire studies at this site

(Peters et al. in prep). Blue grama recovery was faster and this species occurred on a number of plots that were previously dominated by black grama. Soil samples are also being analyzed for each patch type.

Additional grants in collaboration with the Sevilleta LTER Program:

1. Influence of shrub invasion on water and nutrient cycling
   NSF Hydrology, $173,000, January 2001-December 2003.
   PIs: Eric Small; Jan Hendrickx.

2. Hydrological applications of remote sensing: Natural resource analysis and management in New Mexico.
   NSF EPSCoR, $710,000 to NMT Hydrology, January 2002-December 2005.
   PI: Eric Small

3. Coupled plant-water-soil response to multiyear drought in semiarid ecosystems.
   NSF Science and Technology Center for Sustainability of semiArid Hydrology and Riparian Areas (SAHRA). $200,000. Jan 2000 – Dec 2004.
   PI: Eric Small

4. Regional variation in direct and indirect influences of animals on Chihuahuan desert grasslands.
   NSF, LTER Cross-site program, $200,000. 2001-2004.
   PI: D.P.C. Peters.

5. US-Hungary grassland comparisons: Biodiversity, disturbance, and landscape mosaics.
   NSF, International Programs. 9/1/01-8/31/04. $150,000.
   PIs: D. P.C. Peters and J. R. Gosz.

6. Prediction of future plant community dynamics for military installations using simulation modeling.
   U.S. Army Construction Engineering Research Laboratory, 6/26/01-7/31/02. $99,036.
   PIs: D.P.C. Peters and K. Havstad.

7. Carbon sequestration potential of Southwestern rangelands.
   Environmental Protection Agency, 8/1/01-7/31/02. $623,600.
   PIs: Monger, H.C., D.P.C. Peters, J.E. Herrick, and J.T. Harrington.

8. The comparative and interactive effects of keystone rodent species, prairie dogs and banner-tailed kangaroo rats on desert grassland communities in central New Mexico and northern Mexico.
   Graduate Research, Project, and Travel (RPT) Grant, Office of Graduate Studies, University of New Mexico, 2002, $200.
   PI: A. Davidson,.

9. The comparative and interactive effects of keystone species rodent species, prairie dogs and banner-tailed kangaroo rats on desert grassland communities of the northern Chihuahuan Desert.
Alin R. and Caroline G. Grove Summer Scholarship, Department of Biology, University of New Mexico, 2002, $2,500.
PI: A. Davidson.

10. The comparative and interactive effects of two keystone rodent species, black-tailed prairie dogs and banner-tailed kangaroo rats on desert grassland communities in northern Mexico.
T & E, Inc., 2001 – 2003, $2,500.
PI: A. Davidson

11. Self-organization of semi-arid landscapes: Tests of optimality principles.
NSF Ecosystems, 1/2000-12/2002, $674,911.
PIs: B. Milne, D. Bader, W. Pockman, and C. Restrepo.

12. Undergraduate Mentorships in Environmental Biology (UMEB): Undergraduate Career Enhancement and Training in Ecological Studies in New Mexico.
NSF, $400,000, 9/1/01-8/31/05.
PIs: R. Parmenter and W. Gannon.

13. The Sevilleta Research Field Station: Development of a Long-Term Sample Processing Laboratory and Storage Facility.
NSF, Field Stations and Marine Laboratories Program, 10/01-9/03, $79,562.
PIs: R. Parmenter and J. Gosz.

14. Biocomplexity: Common mycorrhizal networks: Active or passive channels? Interacting roles of mycorrhizal fungi, soil resources, and plants in carbon and nutrient transfers.
NSF, 1999-2004, $866,286.
M. F. Allen.

15. Schoolyard LTER Program. BEMP, which was initiated in 1996 with a grant from the NSF Informal Science Education Program, has been funded annually since that time by the congressionally authorized Bosque Initiative administered by the U.S. Fish & Wildlife Service. Other major support has come from Bosque School in Albuquerque, where the Black Institute serves as a funding mechanism for BEMP and other monitoring activities in the Rio Grande basin. Small donations in the past year have come from Wal-Mart and Solo Cups, Inc.

III. Contributions of the Sevilleta LTER Program to Human Resource Development.

The Sevilleta LTER has sponsored three formal programs in research training and education, in addition to including graduate and undergraduate students in ongoing LTER research. The three programs are the Research Experiences for Undergraduates (REU) program (including both Site REU and Supplement REU students), the Undergraduate Mentorships in Environmental Biology (UMEB) program (refunded for 2001-2005), and the Schoolyard LTER program. Also, we have collaborated closely with high school biology students to have them work in the field on Sevilleta on a project examining the role of fires on net primary productivity and insect diversity.

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 relate biodiversity to ecosystem NPP in various ecosystem types across the Sevilleta NWR. In addition, beginning in September, 2001, our renewed UMEB Program will continue under the direction of Robert Parmenter and William Gannon. 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.

The Sevilleta Schoolyard LTER program is directed by Co-P.I. Cliff Crawford, and is entitled, "Bosque Ecosystem Monitoring Program/ Sevilleta LTER Schoolyard Program." This program deals with the ecology of the riparian forest ("bosque" in Spanish) along the Rio Grande in New Mexico, and includes students from a number of schools. The Middle Rio Grande of New Mexico and its riparian forest (bosque) have undergone immense human induced alteration in the past 500 years. The start of a comprehensive and inclusive effort to monitor long-term ecological change in the latter is being made by the BEMP/Schoolyard LTER program.

Two new BEMP sites in the riparian forest, or "bosque," were established and completed in 2002. They bring the total of fully operating sites to nine. Not included are two sites now under construction in Albuquerque, one at either end of the city's proposed inflatable drinking water diversion dam on the Rio Grande < 1 km south of the Alameda Bridge. The dam, if finally approved, will enable the city to use as its main source of water San Juan/Chama diversion flows from the Colorado River basin. Surface water would replace much of Albuquerque's presently declining deep aquifer as the city's main source of water.

BEMP's Alameda site is ~150 m downstream of the east end of the proposed dam, while one of the new site's groundwater well clusters is ~150m upstream. The other new site is directly across the river from the Alameda site. Another new site, not yet under construction, is planned to be directly across from the east side upstream cluster. Bosque School, BEMP's partner, is setting up the sites. The City of Albuquerque is funding the construction.

Any changes in the riparian water table caused by the proposed diversion dam will be monitored by students before and after dam construction. This monitoring will provide baseline data for use in managing cottonwoods at the Alameda site that are already stressed by water tables sometimes dropping below 3 m (a depth considered detrimental to cottonwoods and willows on the Bill Williams tributary of the Colorado River.

One of the newly completed BEMP sites is immediately south of Albuquerque's Caesar Chavez Bridge. It was requested by the National Hispanic Cultural Center of New Mexico, located directly east of the site. The Center funded its installation and plans to use the site as part of its Jardines del Bosque, an ecological and cultural project for Hispanic youth in the area. Monthly data collections at the site are being conducted by the School on Wheels, an alternative high school in the Albuquerque Public Schools system. Now dominated by mature cottonwoods, the site was recently cleared of most non-native trees. Many Kellner jetty jacks, used along much of the Middle Rio Grande to control river width and protect levees against floods, were also removed.

The other newly completed site is at the Pueblo of San Juan, just north of the city of Espanola, in an old cottonwood and Russian olive stand that was moderately burned five years ago. EPA funds, obtained by an environmental consultant working with the pueblo, are being used to clear the forest of its non-native trees and create wetlands in the vicinity. The same funding is used to pay a site representative who coordinates monthly monitoring at the site by students attending the pueblo's Ohkay Owingeh Community School. Youth Conservation Corps youngsters monitored the site during the summer. Monitoring shows that during the irrigation season the site's groundwater level is ~1 m below the surface and shallower than that of any other BEMP site. Soils are largely gravel and cobble and are moist enough to promote rapid and very dense development of early succession plants. This is unlike the situation at the Pueblo of Santa Ana's BEMP site closer to Albuquerque. The Santa Ana site was similarly cleared but has more sandy loam soils and a deeper water table, as well as relatively little herbaceous understory vegetation.

The first annual supplement to the *Bosque Ecosystem Monitoring Program (BEMP): First Report: 1997-2000* should be published by the end of October. It will be submitted as a separate document to the Sevilleta LTER Schoolyard Program and added to our web site address at http://www.bosqueschool.org/BEMP/bemp.org. Results of BEMP"s 2001 monitoring were analyzed and are presented in that document.

In the past year BEMP-Schoolyard staff members have given a number of presentations describing our organization and activities. Presentations were given at the following conferences: the Citizens Wetland Monitoring Meeting in Park City, UT, June 18-20; the Galisteo Wetland Program in Galisteo, NM, July 13; the New Mexico Environmental Education Association Meetings in Albuquerque, January 18 and October 23-24, and at Ghost Ranch, NM, September 22-24; the New Mexico Governor's Blue Ribbon Water Committee at Bosque School, April 18; and the Middle Rio Grande Bosque Initiative/Bosque Improvement Group Conference at the New Mexico Hispanic Cultural Center, May 14. BEMP was also briefly described in The University of New Mexico's January 2002 publication *UNM and the Community*.

IV. Contributions of the Sevilleta LTER Program to Educational and Research Resources.

Educational Resources. The Sevilleta LTER Program continued to collaborate with the BBC to create a "virtual field trip" series on DVD for college students. The program will be interactive and allow students to investigate field ecology studies and learn about different ecosystems in the United Kingdom and the American Southwest. Filming for this project took place during the fall of 2001 at the Sevilleta refuge. Final production should be completed in 2002.

Kristin Vanderbilt co-taught an Information Management Workshop in Maputo, Mozambique August 25-26, 2002 for ILTER scientists from throughout southern Africa.

Research Resources. The Sevilleta LTER Program is the major research group using the University of New Mexico's Sevilleta Research Field Station. The LTER program continues to provide the field station with administrative support (Director Parmenter's salary, and salary for the Administrative Assistant, Mrs. Joslyn Garcia), as well as LTER staff to compile data from all weather stations, GIS and ongoing research projects. The field station then provides field support to a large number of scientists and students studying the ecology, geology, anthropology, and climatology of the Middle Rio Grande Valley.