

Sevilleta LTER 1998 Annual Report

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*Sevilleta LTER II: Biome-level constraints on population, community, and ecosystem responses to climate fluctuation.
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I. The Sevilleta LTER Program

Overview. The Sevilleta Long-Term Ecological Research Program (LTER) was initiated in October, 1988, and has focused on a suite of ecological hypotheses concerning climate dynamics and the responses of organisms in a biome transition zone in central New Mexico. The Sevilleta LTER research region straddles several major biomes of the Southwest, and the large geographic scale of the Sevilleta region is important for studies that range from genetics and physiology at the organismal level, to the dynamics of biome transition zones. The region is strongly influenced by the El Niño Southern Oscillation (ENSO), with major fluctuations in precipitation on semi-decadal time scales. To date, 120 LTER research papers have been published or are in press.

Program Organization. In 1997, Dr. James Gosz returned as the P.I. of the Sevilleta LTER Program. Strategic planning for future research directions of the program have continued, with emphasis on the use of the energy/water balance landscape models as an integrating framework for the numerous ongoing studies. Two additional post-doctoral associates are being hired this summer, one to work on watershed-level evapotranspiration models, and the other to link plant NPP and physiological patterns with remotely-sensed imagery. In response to 1997 Site Review Team suggestions, three additional graduate student summer RA's were awarded. A major group emphasis on improved integration of the various LTER studies has been accomplished, and new research efforts to measure NPP have been instituted. Data management efforts have upgraded the Sevilleta Information Management System, and the new Internet homepage has been operational since last fall. All Sevilleta LTER program descriptions and data sets can be viewed at: <http://sevilleta.unm.edu/>

1997 NSF Site Review. The Sevilleta LTER Program had its third-year NSF Site Review in September, 1997. The review committee provided an evaluation of the program, and made several suggestions for program improvement. Those suggestions have all been positively addressed, and are noted accordingly in the report below.

II. Research Activities

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

A. Landscape Water Balance Modeling

Water balance model and parameterization (Bruce Milne and Scott Martens). The effort to implement a daily time step water balance model for the 1.08 million 30-m cells that compose the Sevilleta has continued. Major accomplishments include completion of a vegetation map for the site. Map products include estimates of plant

community types (both using a site-specific classification and the IGBP method of Steven Running), plant height, plant cover, and leaf area index. The maps were constructed using 12 Landsat TM images and over 200 field plots collected jointly with the New Mexico Heritage Office from 1994-1996. Ongoing development of the model, SPLASH (see below), by Dr. Scott Martens uses the vegetation maps as inputs. A preliminary version of the model uses spatially distributed precipitation estimates, vegetation, soils, temperature, and solar radiation to model potential evapotranspiration, actual evapotranspiration, and water deficit. In the near term, these variables will be used to estimate net primary productivity. Analyses of the vegetation and LAI maps have provided evidence for nonequilibrium processes in the Sevilleta (Milne, in press) and for explorations of scaling issues related to forthcoming sensors such as MODIS (Milne and Cohen, in review).

SPLASH Model Description (Bruce Milne and Scott Martens). The spatially explicit hydrologic model SPLASH (Simulator for Processes on Landscapes: Surface/subsurface Hydrology) has been implemented for the Sevilleta. SPLASH was extensively modified from its original form to take advantage of existing Sevilleta data sets, better simulate arid land hydrology, and run at a daily time step. The microclimate simulator of SPLASH was extended to use data from Sevilleta meteorological stations and spatial precipitation maps derived from lightning strike data. The new Sevilleta vegetation map provides information on plant functional groups for the model. Plant phenology data provide scaling of annual leaf area index curves. Better estimation of soil surface evaporation has been included by a new submodel appropriate for arid lands. Calibration and validation has been accomplished with soil moisture measurements by time-domain reflectometry. Results underscore the major importance of soil evaporation in evapotranspiration from the land surface at the Sevilleta. A version of SPLASH that runs at a daily time step has been accomplished by removing explicit computation of lateral flows of surface and subsurface water. SPLASH is also a central component of the Coupled Environmental Models project at Los Alamos National Laboratory where it is being coupled with a mesoscale atmospheric model, river channel model, and deep groundwater model. Current and future SPLASH development for Sevilleta include model testing with existing Sevilleta data sets, incorporation of the photosynthesis and primary production modules, and prototyping a web-based user interface.

B. Vegetation: Ecotone Studies, NPP, Plant Populations

Ecotone Dynamics (Bruce Milne, Larry Li). During the last year, we have focused on the vegetation transect data and TM image data analyses. The vegetation transect data have been cleaned for analyses of wavelet and multifractal analyses for the Deep Well and Five Points sites. Preliminary results demonstrate that these methods are useful for detecting change in ecotones in terms of multiscale features and fluctuation variance levels. These methods also can characterize seasonal and annual changes at each site. Linking these analyses with meteorological data is in progress. Portions of the results have been presented in the International Ecological Association (INTECOL) Congress in Florence, Italy in July, 1998. Analyses of the TM satellite images demonstrated that the NDVI data were not suitable for our space-time multifractal analysis because of the influence soil reflectance on the pixel signature. A soil-adjusted vegetation index (SAVI) is being developed for further analyses of satellite data. Analysis of all vegetation transects for 1989-98 can be found at:

<http://sevilleta.unm.edu/data/archive/plant/>

Primary Production Studies (David Lightfoot and James Gosz). We have initiated measurements for above-ground plant net primary production (NPP) at the Sevilleta, following recommendations from the 1997 NSF site review. These measurements will provide us with detailed measures of NPP at the plant species level, across four principal vegetation zones at the Sevilleta. NPP measures will be taken from newly established quadrats located in association with rodent trapping webs in the following four vegetation zones: Chihuahuan Desert creosotebush shrubland, Chihuahuan Desert/Great Plains grassland, Colorado Plateau/Rocky Mountain juniper savanna, and pinyon/juniper woodland. We are modeling our NPP methodology after NPP measures that have been perfected at the Jornada LTER. We have consulted with personnel at the Jornada (Dr. Laura Huenneke, and John Anderson), and designed a sampling protocol exactly as done at the Jornada in similar vegetation communities. We have installed NPP quadrats in creosotebush, grassland, and pinyon/juniper woodland habitats at the Sevilleta. We will also establish NPP quadrats in a juniper savanna site, once that site has been installed

later this summer. We are currently training our summer vegetation study technician crew for the new NPP measurement techniques, and making test measurements in each of the four vegetation zones. The plant NPP measurements will provide us with seasonal and annual above-ground plant productivity measures, to the species level, to compare directly with rodent and arthropod data that are currently being collected from the same locations. These new NPP data will allow us not only to monitor the effects of variation in climate on plant productivity across the Sevilleta, but also to relate variation in plant productivity to variation in animal populations and community dynamics across the Sevilleta.

Plant Population Studies of Important Grass Species (Debra Coffin, USDA-ARS; Tamara Hochstrasser, CSU). We are continuing our plant population studies of dominant species found in Chihuahuan desert ecosystems (black grama and creosotebush) and Great Plains grasslands (blue grama). Our focus in 1997 was to evaluate relationships between spatial patterns of individual plants of black grama and creosotebush to provide a better understanding of invasion dynamics. We found that patterns in vegetation do not reflect patterns in soil properties, and that small disturbances may be important to the continuing invasion by creosotebush. We are expanding this work to include sampling for mycorrhizal infections on black grama plants as related to distance from creosotebush plants. We expect the rate of infection will decrease as the distance between black grama and creosotebush decreases due to allelopathic effects from shrubs. Sampling was conducted in a black grama-creosotebush transition zone at the Sevilleta as well as at the Jornada Experimental Range LTER in order to provide a cross-site comparison. This work is being conducted in conjunction with a related study to isolate the allelochemicals from creosotebush plants and associated soils being conducted by Paul Hyder and Ed Fredrickson of the USDA-ARS/JER-LTER. We are continuing our simulation model analyses of soil water and vegetation dynamics based upon our plant population studies. We used the SOILWAT model to evaluate the importance of climatic variation to patterns in recruitment by blue grama and black grama. We found that the two species have different regeneration strategies. Blue grama establishment occurs from June-October whereas black grama is dependent upon rainfall in July and August. Climatic conditions from 1949-1968 favored black grama establishment compared to the cooler, wetter conditions from 1969-1988 that favored blue grama. We are using the ECOTONE model to evaluate the importance of soil development constraints to the response of grasslands and shrublands to changes in climate. Recent predictions from biogeographic models suggest that changes in climate in the Southwestern U.S. will provide conditions more favorable for growth of C4 perennial grasses, such as black grama, compared to C3 shrubs, such as creosotebush. We incorporated the importance of soil organic matter to recruitment and growth of plants in order to predict the site conditions under which recovery of grasses is expected to occur compared to sites where recovery will be constrained by low soil organic matter soils. We found that recovery times range from decades to centuries and longer depending on the initial soil conditions. We are continuing our modeling efforts and will expand them by including the JER-LTER in our cross-site comparisons.

Climate variability and pinyon pine demography. (Julio Betancourt, USGS-Desert Laboratory; Tom Swetnam, Laboratory of Tree-Ring Research, University of Arizona; and Jerry Gottfried, USDA-Forest Service, Tempe, AZ.)

This project was finished at the beginning of the reporting year, and the data have been presented at several workshops on climate change impacts on the Southwest. Dendrochronological methods were used to determine the ages (births and deaths) of 850 seedlings, and more than 2000 living and dead trees in the Sierra de los Pinos back to late 1500s. The inclusion of dead trees in our analysis permits reconstruction of dynamic age structures after 1850. Ancillary data collected at each of our five plots (four 0.5 ha and one 11 ha plot) include diameter at root crown, tree height, and canopy dimensions for all pinyons and junipers in the plots. We also sampled soils under living and dead pinyons of known age to evaluate the stability of soil pH, phosphorous, carbon, and nitrogen content 50-100 years after the trees died.

Recruitment episodes are strongly episodic, with major events represented at two or more of the plots in 1630-1670, 1710-1730, 1770-1790, and 1900-1920. Based on the seedling and sapling data, there also appears to be a pulse in recruitment since 1976. The period from 1942-1956 accounts for most of the mortality evident in the vast number of dead trees across the Sierra de los Pinos. This event eliminated most trees established before 1850,

shifted the age distribution to younger trees, and decreased the proportion of pinyons to junipers at all of the plots. Below the litter layer, we found no differences in soil carbon and nitrogen between living trees and trees that have been dead for 50 to 100 years. We aggregated births and deaths across all of the plots and compared demographic trends with regional climate reconstructions from tree rings. This comparison suggests the following model for the long-term behavior of these woodlands. First, broadscale mortality during catastrophic droughts, such as 1575-1595, 1667-1680, 1730-1750, 1890-1904, and 1942-1957 release existing seedlings and saplings from competition for light, water and nutrients and open up niches for recruitment. A preferred niche might be the footprint of a dead tree (a pool of soil and carbon and nitrogen), which persists for 100 years or more. Recruitment pulses tend to occur in the first sustained wet period following the drought and the associated mortality. An example of this process may be the pulse in recruitment since 1976, on the heels of the mid-century drought and sustained by a string of wet winters linked to anomalous warming of the tropical Pacific. Most recently, we have expanded the seedling part of our study to other areas in the middle Rio Grande Basin to discriminate between climate and grazing effects (e.g., fencing of the Sevilleta in 1976). Finally, our study underscores the importance of reconstructing, observing, and assessing ecological processes and patterns at the appropriate scales, i.e., mesoscales and centuries. Ecological synchronicity at these scales is the hallmark of climatic effects on ecosystems and is a key to separating cultural from natural causes of environmental change.

C. Climate/Meteorology and Precipitation Chemistry (Doug Moore)

1998 marks the end of the first decade of meteorological data from continuous monitoring weather stations on the Sevilleta National Wildlife Refuge. During this period the refuge has experienced 2 strong El Niño episodes and 2 La Niña episodes with a third La Niña possibly developing. In addition to the standard meteorological measurements monitoring of soil parameters such as temperature and moisture content is ongoing. Direct measurements of evapotranspiration also continues using a Bowen Ratio station. Complete hourly meteorological data sets for 1989 through 1997 are available on the Sevilleta Home page at:

<http://sevilleta.unm.edu/data/archive/climate/meteorology/>

Efforts continue on archiving lightning strike data to be used for predicting monsoon precipitation across the Sevilleta. We are lending our weather data to the U.S. Bureau of Reclamation scientists, who are attempting to calibrate NEXRAD (NEXt generation weather RADar) precipitation estimation model for the entire middle Rio Grande Basin. We will then need to compare these estimates with those calculated from lightning.

1998 will also complete 10 years of quantification of nutrient inputs in precipitation. Collection and analysis of bulk precipitation continues to be done at 6 sites on the Sevilleta while wet and dry samples are also being collected and analyzed at 2 of these 6 sites. Archived precipitation chemistry data can be found at:

<http://sevilleta.unm.edu/data/archive/nutrient/precipitation/>

The Sevilleta continues to maintain one of the LTER-NASA sun photometers. This automatic sun-sky scanning spectral radiometer collects aerosol spectral optical depths, aerosol size distributions, and precipitable water measurements as part of a world-wide network - AERONET (AERosol RObotic NETwork) of such instruments. This instrument has been in operation since 1994. The data from this instrument as well as the others in the network are maintained by NASA but can be accessed via the NASA Home page at:

<http://spamer.gsfc.nasa.gov/>

D. Nutrient Cycling and Soil Ecology. (Carl White and John Craig)

Primary inputs to ecosystems are determined from chemical analyses of bulk precipitation and the wet/dry collectors (see meteorological section). Annually, replicate litter bags of last year's production of black grama, juniper, Indian rice grass, and creosote are placed at 4 core sites to measure decomposition: Deep Well; Cerro Montosa; Rio Salado; and Red Tank. Collections are made seasonally through the first year and after two years. A fifth species, blue grama, is placed at the Deep Well site also, which represents the most extensive mixture of blue and black grama. The Deep Well site is also a site represented by the LIDET inter-site decomposition study. All data should be available on the web by the first of the year. Our summer REU student is conducting a research

project on the effects of moisture and temperature on nitrogen mineralization potentials. Data from this project will be available on the web by the end of the summer.

At the four core sites, soil erosion bridges (five at each site) were installed and are measured to monitor changes in soil microtopography (erosion/deposition). Associated soil analyses include texture, water holding capacity, organic matter, nitrogen mineralization potential, total N and P, and soil conductivity. A pilot study on cryptogamic crusts was carried out in May in conjunction with the NASA/ADAR collaboration. Information about all nutrient cycling studies at the Sevilleta are available on the web at:

<http://sevilleta.unm.edu/research/local/nutrient/soil/>

E. Trophic Interactions/Animal Population Studies.

Vertebrates. (Parmenter, Yates, Brown, Friggens, Lightfoot). 1998 is the tenth consecutive year for the spring and fall rodent trapping for the Sevilleta LTER Small Mammal Population Study core dataset. Forty percent of the trapping effort generates material for continuing investigation of taxonomy and population trends of host parasites. This research measures mammal densities at six localities representing the major biomes on the SNWR. A four person crew has completed six weeks of field work this year. We have observed a dramatic population increase this year over the two past drought years, especially within the family Muridae, which may indicate a resurgence of human disease cases of *Sin Nombre* Hantavirus. Additional ongoing mammal studies include population density estimates of rabbits and coyotes. In collaboration with Dr. Lucina Hernandez, Director of the Mapimi Research Station, Instituto de Ecologia, Mexico, we have analyzed diet changes in the Sevilleta coyote populations from scats collected from 1992 through 1997; a manuscript is in preparation from these data. Mammal data can be viewed at: <http://sevilleta.unm.edu/data/archive/animal/mammal/>

The Bird Population Trend study consists of seasonal point counts in three habitat types on the Sevilleta. The bird densities are also up this year, largely a result of bountiful seed crops produced last fall. Bird data can be viewed at: <http://sevilleta.unm.edu/data/archive/animal/bird/>

Arthropods (Sandra Brantley, Robert Parmenter, David Lightfoot). As part of an effort to streamline our research activities, and to focus on particular research questions (effects of long-term climate variation across principal biotic communities), we intend to reduce the number of pitfall trap study sites. These changes are in response to recommendations from the 1997 NFS site review. We have continued sampling all sites through 1997/1998 to provide us with ten years of data from those sites. In 1999, we will discontinue sampling all sites on the west side (which are largely redundant with sites on the east side) of the Sevilleta, and will concentrate on the east side. We will focus our research on four primary vegetation zones that are representative of the Sevilleta; Chihuahuan Desert creosotebush shrubland, Chihuahuan Desert/Great Plains grassland, Colorado Plateau/Rocky Mountain juniper savanna, and pinyon/juniper woodland. We have improved on our sample sorting, data entry, and reference collection curation methodology. We are now contracting two expert entomologists to sort, identify, tabulate, and enter the arthropod sample data, and to curate the reference collection. We recently received a funding supplement from NSF to enhance our reference collection, and to help interface the LTER reference collection with the main arthropod collection at the Museum of Southwestern Biology. We have begun a database for the MSB and the LTER arthropod reference collections, utilizing Biota database software. We have implemented new alpha species codes for all arthropod taxa, and have re-structured the arthropod database files on SIMS for easier access and better organization of data and metadata files and directories. Species distribution data from the Sevilleta continue to contribute to statewide efforts to inventory arthropod diversity by documenting range extensions and undescribed species. Data can be found at: <http://sevilleta.unm.edu/data/archive/animal/arthropod/>

F. Disturbance Studies

Wildfires. (Robert Parmenter, James Gosz, David Lightfoot, Debra Coffin). The Sevilleta NWR experienced a lightning-ignited, 1,000+ ha wildfire on 30 June, 1998. The fire would have consumed a large portion of the Sevilleta northeastern grasslands, had not the presence of pre-existing roadways prevented the fire's spread. This fire demonstrated very clearly the importance of wildfire in the ecology of ungrazed grasslands in New Mexico.

Within one week after the fire, the LTER and US Fish and Wildlife Service conducted high-resolution aerial photographic surveys of the burned area; these photos will allow a comparison of vegetation patterns before and after the fire (the LTER has a complete set of high-resolution aerial photographs of the entire 100,000 ha Sevilleta NWR, as acquired with supplemental NSF/FWS funding in 1993). In addition, Debra Coffin has established vegetation sampling plots in the fire area, and is working with Jornada LTER researchers in comparing fire effects at Sevilleta with Jornada and the Gray Ranch in SW New Mexico (BLM funded study).

As part of previous LTER fire studies using controlled experimental burns, post-fire measurements of vegetation re-growth is continuing for experimental and natural fire sites on the Sevilleta. Results to date show differences in recovery and NPP of black grama vs. blue grama (Gosz and Gosz 1996), and survivorship and species-specific regrowth rates have been determined for all common species of perennial plants in the Sevilleta grasslands (Parmenter et al., in preparation). Animal responses to fires are negligible, with most species avoiding the fire and surviving normally in the post-fire environment. One paper has been published showing the details of harvester ant foraging behavior after the fires (Zimmer and Parmenter 1998); eight more manuscripts on plants, rodents (2), pronghorn, beetles, grasshoppers, spiders, and homopterans are in preparation.

Prairie dog reintroduction project. (James Gosz, Robert Parmenter, REU-Ana Davidson). A population reintroduction of Gunnison's prairie dogs was begun in March 1997 in the grasslands near the South Gate region of Sevilleta. The influence of the prairie dogs on vegetation and other rodent species during the first year of reintroduction was found to be non-significant, although future changes are expected. Survival of the prairie dogs through the first year was estimated at approximately 50%, and successful reproduction of young during 1998 was observed. Future studies, including collaborative cross-site research with SGS LTER, are being planned. A manuscript on results to date has been prepared, and will be submitted in August, 1998.

Plant Responses to Small Scale Disturbances (Debra Coffin). We are continuing to evaluate the effects of small, patchy disturbances on vegetation dynamics at ecotonal boundaries through experiments and simulation models. We are continuing to monitor our 3m x 4m removal plots at five sites located along a grassland-shrubland ecotone on McKenzie Flats. We added in sixth site along the foothills of Los Pinos in April (1998). This site represents a predominately blue grama community with very small amounts of black grama and no creosotebush. The site also contains a number of Great Plains grassland species, and is the most similar site vegetatively at the Sevilleta NMW to the SGS LTER. Thus, this site will provide data for cross-site comparisons with similar research conducted in northern Colorado. We also evaluated the effects of kangaroo rat mounds on dominance patterns by blue grama and black grama. We sampled vegetation on and off mounds located in patches dominated by one of the two grama species. We found that blue grama is negatively affected by the presence of kangaroo rat mound and black grama is positively affected by the mounds. We also analyzed the long-term vegetation transect data to determine the relative importance of patchy disturbances and climate to species diversity and composition. We found that patchy disturbances are as important as El Niño events in generating and maintaining patterns in species diversity.

Riparian Flooding and AET. (Cliff Dahm, Manuel Molles, Cliff Crawford, Maury Valett, Padinare Unnikrishna, Terri Mulhern). Eight sites are being established along the riparian gallery forest of the Rio Grande during the summer and fall of 1998 to study evapotranspiration from these ecosystems. Sites include areas dominated by native cottonwoods and exotic saltcedars. Four sites are in areas that receive regular flooding and four sites are in areas decoupled from the river. The project is funded through a NASA ecosystem restoration program, and one site in an unflooded saltcedar stand is located at the Sevilleta. Evapotranspiration from the sites will be measured with ground water mass balance, modified Penman Monteith, Bowen ratio, 3-D sonic anemometry, and satellite remote sensing. The objectives of the project are to 1) determine annual evapotranspiration rates for native and non-native riparian plant communities using multiple techniques, 2) assess the effect of regular flooding relative to long inter-flood intervals on annual evapotranspiration rates, 3) compare remote sensing, water balance, and micrometeorological techniques for estimating evapotranspiration, and 4) scale up plot measurements of ET to provide an annual reach estimate of riparian ecosystem water use. Field measurements to accomplish these goals are planned for 1999 and 2000.

G. GIS/Remote Sensing.

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

Development of the Sevilleta Vegetation Map. (Bruce Milne, Esteban Muldavin, Greg Shore). A final vegetation map with nominal 0.5 ha resolution has been finished for the Sevilleta. The map includes 13 vegetation classes derived from an unsupervised classification of 12 Thematic Mapper images collected in three seasons over a four year period. Plant composition, height, and cover were measured at three or more ground points for each class. Esteban Muldavin of the New Mexico Heritage Program, has completed a plant classification at the association level from which 32 classes were combined, thereby enabling direct comparison with other mapping efforts in the state, i.e., The Gray Ranch, Melrose Missile Range, White Sands National Monument, Cannon Air Force Base. The data soon will be available on-line at: <http://sevilleta.unm.edu/data/archive/gis/#vegetation>.

GIS Database Layer Development (Greg Shore). We worked with Positive Systems, Inc. (PSI), under contract with NASA, to acquire digital aerial photography of the Sevilleta NWR at 1 meter resolution, using the PSI ADAR 5500 Multi-spectral Scanner (which emulates the first 4 bands (B,G,R,NIR) of the Landsat TM sensor). Data products include 30% sidelap/overlap 1500x1000 m frames, as well as mosaiced complete coverage of the Sevilleta NWR. Project information is available on WWW at: <http://sevilleta.unm.edu/collaboration/nasa/adar/> with imagery soon to be available at: <http://sevilleta.unm.edu/data/archive/imagery/airphoto/>

In addition, we have continued work on design and implementation of GIS/RS data management, archiving, and WWW access (including access security measures). Examples available at:

<http://sevilleta.unm.edu/data/archive/imagery/satellite/>

We also have negotiated new agreements with ERDAS and ESRI for more functional and cost-effective GIS/RS software packages for UNM and the Sevilleta LTER. Finally, we designed and conducted an "Introduction to GPS" workshop as part of the annual ESA conference held in Albuquerque, NM, in August, 1997.

H. Cross-site Activities.

Chihuahuan Desert small mammal exclosure study with Jornada LTER and Mapimi, Mexico (David Lightfoot and James Brown). We continue to make routine measurements on the small mammal exclosure study plots at the Sevilleta. Vegetation quadrat measurements, including plant canopy cover, plant species composition, and soil surface disturbance were measured on all quadrats in the autumn of 1997, and early summer of 1998.

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

Ground-dwelling Arthropods: Bandelier/Sevilleta/Jornada (David Lightfoot). We have implemented the same sampling design and protocols for monitoring ground-dwelling arthropods at the Jornada LTER site (NSF funding to the Jornada LTER program) in southern New Mexico, and at Bandelier National Monument (USGS-BRD funding) in northern New Mexico. This extends the Sevilleta ground-dwelling arthropod studies to a regional

level, encompassing an environmental gradient from the southern Rocky Mountains to the northern Chihuahuan Desert. All three study areas include a variety of major habitat types, and elevation gradients. We are coordinating sampling times, target arthropod groups, and data formatting at all three sites. We will continue these efforts through 1999. We have acquired additional funds from DOE to add another site in the Jemez Mountains near Bandelier, to focus on the effects of El Niño events on arthropods across an elevation gradient.

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

US-Hungarian cross-site research (Debra Coffin and James Gosz). As part of our US-Hungary project (Coffin and Gosz; INT95-13261), we are conducting cross-site comparisons of vegetation pattern and dynamics at three LTER sites (Sevilleta, SGS, JER) and three dry grassland sites in Hungary. In 1997, two Hungarian students and one US student sampled vegetation at the Sevilleta and SGS sites in June and July. Four scientists from Hungary attended the annual ESA meeting in August held in Albuquerque, then stayed in the US for the month of August in order to sample vegetation at the Sevilleta and Jornada. Our major findings are that species diversity decreases as the aridity of the site increases, in that the diversity was highest at the SGS, and similarly low at the Sevilleta and Jornada. We also sampled species composition in patches dominated by either blue grama or black grama, and found that species richness and identity are very similar in both patch types. Our results indicate that subdominant species from the two biomes (Chihuahuan desert, shortgrass steppe) are not strongly associated with their respective dominant species.

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

At all of the study sites except for Sevilleta, replicated experimental plots receiving 100 to 300 Kg N/ha/yr (as NH₄NO₃) have previously been established by site personnel. In December 1995, we established twenty 5 x 10 m plots at Sevilleta, with half of the plots randomly selected and fertilized with 100 Kg N/ha/yr (half applied in June and half in December). At Shortgrass Steppe the N enrichment treatment was maintained only between 1971 and 1975, but at Kellogg, Cedar Creek, Konza, and Sevilleta, N is currently applied to the experimental plots once or twice a year. Early and late during the growing season, root and rhizosphere soil samples are collected from two dominant grass species (one that increases with N-enrichment and one that decreases with N-enrichment) in N enriched and control plots at each of the sites.

Many interesting and important results are emerging from this research. Total AM colonization, arbuscular colonization and vesicular colonization are quite responsive to N enrichment, however we have not yet observed any consistent changes in arbuscule:vesicle ratios. Mycorrhizal colonization is significantly affected by N treatment at four of the five sites. The Sevilleta mycorrhizae have not yet shown a significant response to the N treatment, but we expect a lag period between N enrichment and mycorrhizal responses. At the other extreme, there appears to be a lag period between the cessation of N enrichment and mycorrhizal responses. Although

experimental N enrichment at Shortgrass Steppe ended 22 years ago, grasses in N-enriched plots still show significantly lower AM colonization than those in the control plots! Similarly, AM colonization at Kellogg and Cedar Creek was significantly reduced by N-enrichment (Figure 1). Also, at Kellogg and Cedar Creek, N-enrichment significantly reduced spore populations of Gigasporaceae (Figure 2), indicating a shift in the species composition of AM fungal communities. Compared to the other grasslands, responses of mycorrhizae at Konza was reversed, N consistently increased AM colonization and spore populations of Gigasporaceae. We hypothesize that this result is due to an interaction between soil N and P. Konza soils strongly fix P and N:P ratios are much higher there than at the other sites. We hypothesize that adding N to Konza soils makes that system more P-limited and thus stimulates mycorrhizal colonization. To further explore this hypothesis, we have expanded our sampling at Konza to include experimental plots enriched with both N and P.

Mycorrhizae are generally assumed to be mutualisms, however there are many cases in which they function as parasitisms. We hypothesize that, in undisturbed grassland systems, plants and AM fungi should be adapted to each other and to the local soil in order to maximize the mutualistic effects of the symbiosis, however anthropogenic enrichment of limiting soil nutrients may perturb their mutualistic functioning. Previous research at the Cedar Creek site supports the hypothesis that fertilization selects for AM fungi that are inferior mutualists to native prairie grasses. At present, we are testing the generality of this hypothesis for each of the five study sites by inoculating the two study grasses (one that increases with N-enrichment and one that decreases with it) with AM fungi from either fertilized or unfertilized plots. Results of these experiments are now being analyzed.

III. Public Outreach

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

In 1997, the Sevilleta LTER was featured on the CBS Evening News in regard to possible Hantavirus problems associated with the 1998 El Niño. As a number of our predictions have come true, Sevilleta researchers Terry Yates and Robert Parmenter have been on national (CBS, ABC, NBC, CNN) and local news presentations discussing the relationships between climate, ecosystem productivity, animal populations and diseases. In addition, Parmenter also appeared on the CBS local news in June, 1998, explaining climate dynamics (droughts) and impacts on water availability and ecosystem responses in New Mexico based on the LTER studies. With respect to transferring LTER concepts and Sevilleta LTER results (as examples) in the international community, James Gosz has appeared on several television broadcasts in a number of foreign countries. This list includes appearances in Ireland, Spain, Taiwan (China-Taipai), Mongolia, and Israel.

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

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

<http://sevilleta.unm.edu/data/archive/gps/>

1997 ESA Meeting. Finally, the Sevilleta LTER group functioned as the "local organizing committee" for the Annual Meeting of the Ecological Society of America in Albuquerque, 11-14 August, 1997.

IV. UMEB/REU Program

The Undergraduate Mentorships in Environmental Biology (UMEB) Program (P.I. Robert Parmenter, plus many faculty mentors) continues to operate in collaboration with the Sevilleta LTER. In addition, in the summer of 1998, there are three REU students funded through an NSF supplement to the LTER Program. 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, (5) a Department of Biology Research Day for project presentations by the students, (6) attendance at scientific meetings, and (7) 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. All of last year's REU/UMEB students volunteered to assist with the 1997 Ecological Society of America meeting in Albuquerque.

V. Network-level Activities.

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

<http://atlantic.evsc.virginia.edu/~jhp7e/modlers/>

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

3. LTER Network Climatology Workshop. Sevilleta hosted the LTER workshop on Meteorological Methods held in October, 1997.

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

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

VI. Additional Grant Support (18 Grants, Total Funding = \$9,153,484)

Sevilleta LTER 1998 Supplement Proposal: REU Students, Research Equipment Upgrades, Museum Equipment Additions, and Schoolyard LTER Program Development. NSF, \$130,000.

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

Longitudinal Studies of Rodent Reservoirs of Hantavirus in the Southwestern United States. Terry L. Yates. Centers for Disease Control and Prevention, 30 September 1997 - 29 September 1998 (pending), \$196,068.

Hantavirus Infections: Ecology, Immunity, and Treatment. Terry L. Yates and Fred Koster. Department of Health and Human Services, 1 Apr 1996 - 31 Mar 2000, \$2,038,472.

Relocation and compactorization of the Museum of Southwestern Biology. Timothy Lowrey and Terry L. Yates. National Science Foundation, 15 August 1996 - 31 July 1998, \$313,200.

Workshop: US/Mexico collaborative long-term research across North American Biomes. Terry L. Yates. National Science Foundation, 1 Sep 1995 - 31 Mar 1998, \$27,180.

Response of Southwestern Montane small mammal communities to global change. Terry L. Yates. US Fish and Wildlife Service, 1 Jul 1994 - 31 Jun 1998, \$250,000.

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

Replacement and consolidation of research training facilities of the Department of Biology, University of New Mexico. Terry L. Yates, Robert R. Parmenter, and Howard Snell. National Science Foundation, 15 Mar 1997 - 31 March 1998, \$960,000 + \$2,300,000 matching funds from UNM. NOTE: This project will fund the renovation of a UNM campus building which will house the new offices, laboratories and museum collections of the Sevilleta LTER Program and the LTER Network Office.

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

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

Ecology of Fire in Semi-arid Grasslands. USDA Forest Service, \$24,876. P.I. Carleton S. White.

Role of climate in masting, recruitment, and mortality of pinyon pine. USDA-Forest Service, Rocky Mtn. Experimental Station, Middle Rio Grande Ecosystem Program, Interagency Cooperative Agreement RM-28-C4-800. Amount \$47,000. 1994-1997. ADOR: Jerry Gottfried. PI: Tom Swetnam, Univ. Arizona, and Julio Betancourt, USGS.

USGS Paleoecological Research at the Sevilleta LTER. DOI, U.S. Geological Survey, Global Change Program: The paleoecological work at the Sevilleta LTER has been done through cooperative agreements where at least half of the resources have been contributed by USGS.

U.S.-Hungary Grassland Comparisons: Response of Vegetation to Environmental Constraints and Global Change. Coffin, D. P., and J. R. Gosz. NSF International Programs (INT95-13261). \$156,076. 1996-1999. REU Support for \$8000 for 1997. Collaborative project with Hungarian ecologists (Edit Kovacs Lang, Sandor Bartha, and Gabor Fekete) funded by the Hungarian Academy of Sciences.

CAAW: Development of Landscape Analysis Techniques and GIS Expertise to Predict Vegetation Dynamics at Ecotones. Coffin, D. P. NSF Career Advancement Awards for Women (DEB97-07100). \$47,380. 1998.

Riparian ecosystem restoration: effects of flooding and vegetation type on annual evapotranspiration in a semi-arid landscape. P.I.'s Cliff Dahm, Manuel Molles, Jr., Cliff Crawford, Padinare Unnikrishna, Maury Valett,

and Terri Mulhern. NASA, \$700,000, 2/1998-2/2001.

Mycorrhizal Responses to Nitrogen Eutrophication at Five Mesic to Semiarid Sites. (1/96-12/31/98)

DEB-9796168 (initially to Univ. of New Mexico as DEB-9527317): \$98,519 , P.I. N.C. Johnson, E.B. Allen is a collaborator with grant DEB-9526564.

VII. 1997-Present Sevilleta LTER Publications

1. Journal Articles

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- Andreas, Edgar L., Reginald J. Hill, James R. Gosz, Douglas I. Moore, William D. Otto, and Achanta D. Sarma. 1998. Stability dependence of the Eddy-accumulation coefficients for momentum and scalars. *Boundary-Layer Meteorology*, 409-420.
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- Kitchell, James F., Daniel E. Schindler, Brian R. Herwig, David M. Post, Mark H. Olson, and Michael Oldham. In Press. Nutrient cycling at the landscape scale: The role of diel foraging migrations by geese at the Bosque del Apache Wildlife Refuge. *Limnology and Oceanography*.
- Milne, Bruce T. In Press. Motivation and Benefits of Complex Systems Approaches in Ecology. *Ecosystems*.
- Mitchell, R.J. In Press. Effects of pollen quantity on progeny vigor: evidence from the desert mustard *Lesquerella fendleri*. *Evolution*, 51:.

- Mitchell, R.J., and D.L. Marshall. In Press. Nonrandom mating and sexual selection in a desert mustard: an experimental approach. *American Journal of Botany*.
- Mitchell, R.J. In Press. Effects of pollination intensity on *Lesquerella fendleri* seed set: variation among plants. *Oecologia*.
- Molles, M. Jr., C. S. Crawford, L. M. Ellis, H. M. Valett, and C. N. Dahm. 1998. Managed Flooding for Riparian Ecosystem Restoration. *BioScience*, in press (September issue).
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2. Book Chapters

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- Milne, Bruce T., Alan R. Johnson, and Steven Matyk. In Press. ClaraT: Instructional software for fractal pattern generation and analysis. In, J.M. Klopatek and R.H. Gardner (eds.). *Landscape Ecological Analysis: Issues and Applications*. Springer-Verlag, New York.
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3. Other Publications

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- White, Carleton S., Samuel R. Loftin, Steven C. Hofstad. In Press. Response of Vegetation, Soil Nitrogen, and Sediment Transport to a Prescribed Fire in Semiarid Grasslands. In: D.M. Finch (ed.). Rio Grande Ecosystems: Linking Land, Water, and People. Proceeding of a symposium, June 2-5, 1998, Albuquerque, NM. USDA Rocky Mountain Research Station, Fort Collins, CO.