Activities

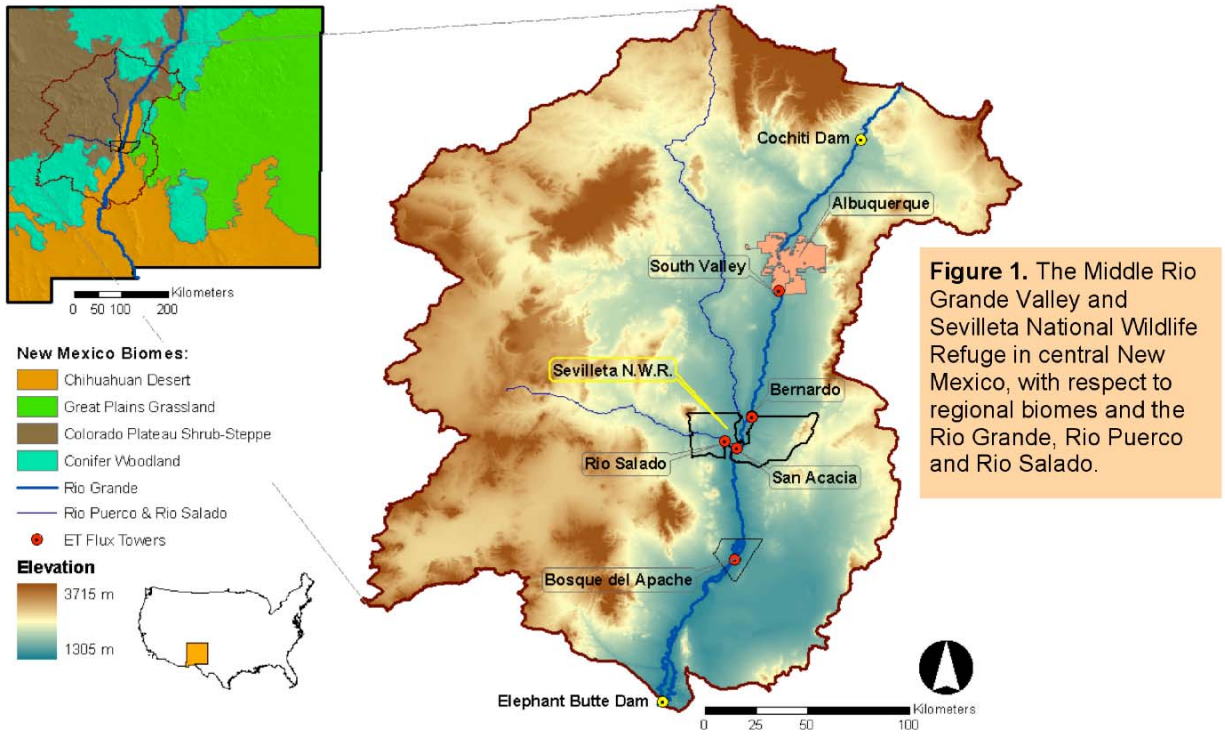


Figure 1. The Middle Rio Grande Valley and Sevilleta National Wildlife Refuge in central New Mexico, with respect to regional biomes and the Rio Grande, Rio Puerco and Rio Salado.

The Sevilleta LTER Program addresses ecological concepts and theory through a comprehensive and interdisciplinary research program in desert grassland, shrubland, forest and riparian habitats in central New Mexico. Our focal sites are the 100,000-ha Sevilleta National Wildlife Refuge (SNWR) located about 80 kilometers south of Albuquerque (managed by the US Department of the Interior, Fish and Wildlife Service) and the Middle Rio Grande (MRG) bosque between Cochiti Dam and Elephant Butte Reservoir (Fig 1). Since its inception in 1988, the Sevilleta LTER program has conducted research at multiple ecological levels and a variety of spatial and temporal scales. Our studies are linked by an overarching theme that considers **how abiotic drivers and constraints affect dynamics and stability in aridland populations, communities and ecosystems.**

The Sevilleta LTER Program is a long-term, comprehensive, integrated, interdisciplinary research program addressing key hypotheses on pattern and process in aridland ecosystems. Our LTER research in central New Mexico is concentrated on studies in desert grassland and shrubland communities and piñon-juniper and riparian (‘bosque’) woodlands emphasizing transitions in space and time. Each landscape component is governed by key abiotic and biotic drivers, especially climate variability, fire, hydrologic variability, nutrient dynamics, and herbivory. The rates and intensities of these drivers are changing over time. Given the emerging research interest in ecohydrology of aridlands, our focus on the effects of biotic and abiotic drivers on spatial and temporal dynamics of these aridland ecosystems allows us to conduct long-term research that addresses important basic ecological questions and yet has significant relevance to state, regional, national, and international priorities.

The Sevilleta LTER site and its surroundings are positioned at the intersection of several major biotic zones: Chihuahuan Desert grassland and shrubland to the south, Great Plains grassland to

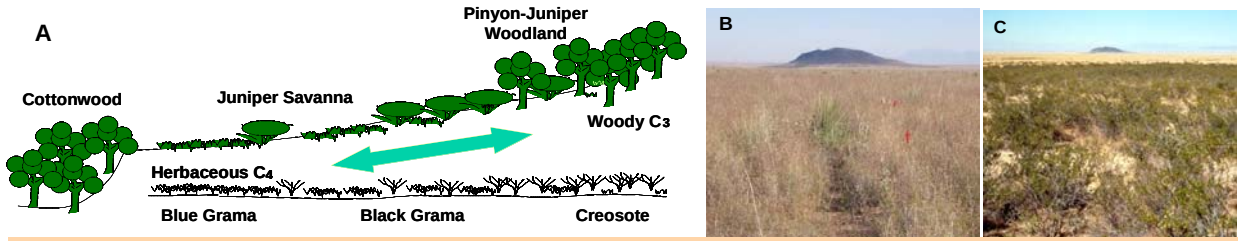


Figure 2. A) Schematic diagram of upland transitions at the Sevilleta National Wildlife Refuge. B) Black and blue grama grassland at Deep Well. C) Creosote dominates 4 km south.

the north and east, piñon-juniper woodland at upper elevations in the mountains, Colorado Plateau shrub-steppe to the north and west, and riparian vegetation along the middle Rio Grande Valley (Figs 1 and 2). Because of the confluence of these major biotic zones, the SNWR and the Middle Rio Grande Basin present an ideal setting to investigate how environmental change and climate variability interact to affect ecosystem dynamics at the boundaries of major biomes in southwestern North America. Moreover, the rapid growth and southern expansion of the City of Albuquerque and its suburbs increasingly will have an impact on ecosystem processes throughout the Middle Rio Grande Basin, including the SNWR, and these urban forces will interact with climatic variation to catalyze change in this aridland region.

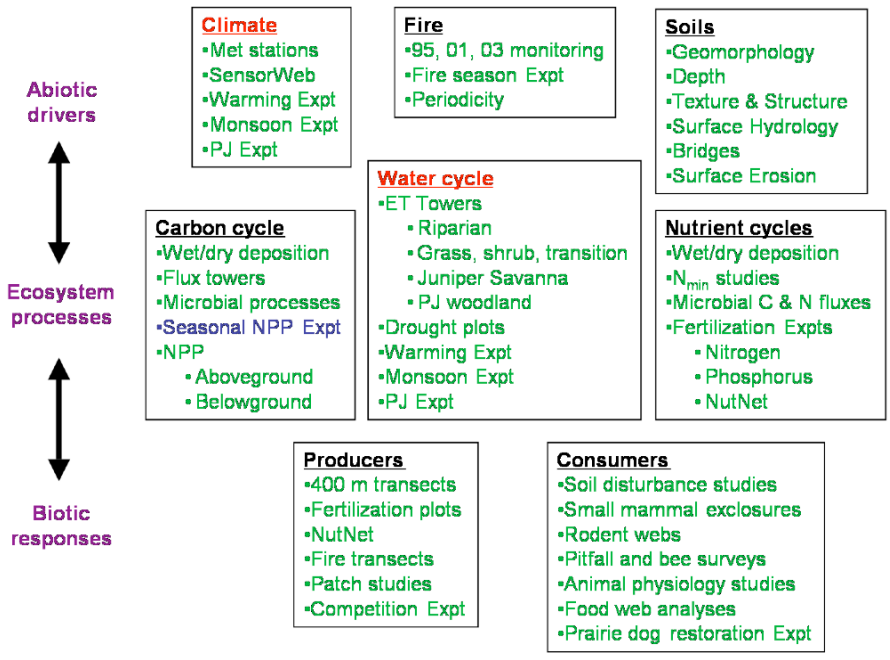


Figure 3. **Current** (GREEN) and **Planned** (BLUE) activities of the Sevilleta LTER Program, with a major focus on climate and water cycle interactions

This is the second annual report from our fourth funding cycle. LTER IV (2006-2012) builds on our prior research on patch and boundary dynamics by placing a greater emphasis on interactions among key processes and drivers of change in aridland ecosystems, in particular nitrogen (N) availability and climate dynamics. This new emphasis greatly expands the spatial and temporal scales and conceptual bases of our LTER program. Our new organizing framework is designed to integrate the components of our research program and allow us to test important hypotheses of general ecological interest.

More specifically, Sevilleta research is designed to understand the individual and interactive effects of three key system components: abiotic pulses and constraints, ecosystem processes, and biotic responses and feedbacks (Fig 3). The main abiotic *pulses* and *constraints* are (1) seasonal, annual, and decadal variations in climate, (2) geomorphology, soil texture, structure and depth, and surface and riparian hydrology, and (3) season, periodicity, and intensity of fire. These abiotic factors affect *dynamics* of biogeochemical pools and cycles; water input, storage, use and loss; and patterns and controls on primary production. Biotic responses to the coupling of these abiotic factors and ecosystem processes include *dynamics* and *stability* in the distribution, abundance, and diversity of plant and animal populations and communities. Given the fundamental relationship between primary production and community structure in ecological communities, one of our core LTER activities is to link climate dynamics, disturbances, and soil structure with soil nutrient and water fluxes to better understand seasonal and annual variability in NPP and how that variability ultimately affects the dynamics, distribution and abundance of key aridland producers and consumers.

Figure 4. Photo of irrigation event in the piñon-juniper rainfall manipulation experiment in the Los Piños Mountains at the Sevilleta LTER.

To accomplish these goals, the Sevilleta LTER program is organized into five overlapping thematic areas with designated group leaders: Climate and Abiotic Drivers (Cliff Dahm), Water Fluxes (Will Pockman), Soils and Biogeochemistry (Bob Sinsabaugh), Producer Dynamics (Esteban Muldavin), and Consumer Dynamics (Blair Wolf). These thematic areas are not mutually exclusive, but they serve as an effective mechanism to organize and synthesize our research. New and continuing research includes a variety of activities in each sub-area (Fig 3).

In 2008-2009 we continued all but one long-term data collection efforts described in our renewal proposal (LTER IV) and in the 2007-2008 annual report. These activities include (1) our multiple factor global change experiment that manipulates nighttime temperature, N-deposition, and winter rainfall frequency, (2) a summer monsoon rainfall manipulation experiment, (3) our rainfall manipulation experiment in piñon-juniper woodlands (Fig 4), (4) expanded efforts to restore Gunnison's prairie dog colonies on the Sevilleta, (5) use of stable isotopes to understand food web dynamics, with specific focus on grasshoppers, lizards (Warne et al. 2009) and box turtles, and (6) monitoring of CO2 and H2O fluxes in riparian, grassland, shrubland, grass-shrub transition zone, piñon-juniper woodland, juniper savanna and mixed conifer forest. Also in 2008-2009, a number of Sevilleta LTER graduate students and REU students have conducted important short-term measurements and experiments on climate, biogeochemistry and soils,

water and nutrient cycling, producer, and consumer communities. Highlights of results from a subset of these activities are provided in "Findings."

Riparian ET and water fluxes

The riparian corridor of the Rio Grande on and near the Sevilleta LTER has been the focus of long-term ecohydrological and bio-meteorological studies. An eddy covariance flux tower was installed in the spring preceding the 1999 growing season and has been operating since. This tower was initially installed to measure evapotranspiration and energy fluxes. Supporting activities have included vegetation surveys, plant water relations measurements and studies, groundwater dynamics and chemistry, scaling and classification using remote sensing, remote data collection using telemetry, and characterization of the surface layer for water, energy, and carbon dioxide fluxes.

Producer dynamics in response to disturbances

We continue to examine the effects of small, patchy disturbances on vegetation dynamics across grassland-shrubland ecotones. Five sites have been monitored since 1995 and the sixth was added in 1998. At each site, five 3 m x 4m plots were established by removing all plants of the dominant vegetation. An additional 5 control plots with no removals serve as controls at each site. We also added a series of 5 plots with total removals at each site in 2003. Sites are dominated by either blue grama, black grama, blue and black grama, creosotebush, or black grama and creosotebush. We monitor vegetation cover by species annually on each plot. Long-term monitoring is needed to determine the species that will dominate following the loss of the current dominant.

Simulation modeling

In collaboration with the JRN LTER, we continue to modify the ECOTONE simulation model by incorporating the horizontal and vertical distribution of water, nutrients, and soil particles by wind and water across a range of spatial scales, from plants to patches and landscape units. We are working with Greg Okin at UCLA to link ECOTONE with his model of wind redistribution of soil particles to incorporate effects of dynamic vegetation on wind erosion-deposition dynamics. We recently started working with Enrique Vivoni of NM Tech to link ECOTONE with his hydrologic models. In addition, we have an ARS postdoc at the JRN who is working with SEV Senior Scientist Deb Peters and Ed Fredrickson to develop an animal model to link with ECOTONE as part of our overall ENSEMBLE modeling effort.

Significant events in 2009

Two significant events occurred in August 2009. On 4-5 August 2009 multiple dry lightening strikes, 48.3 kph winds, and 38^{o}C temperatures combined to create a wildfire that burned nearly 3200 ha of desert grassland at the Sevilleta. This fire burned through several of our major climate change experiments including our monsoon rainfall manipulation experiment (MRME), annual drought and rainfall augmentation plots, and our nighttime warming, winter rain, N deposition experiment ("warming"), as well as our grassland flux tower site. Most of the fire damage was confined to shelter infrastructure at warming and nearly all cables to soil moisture, temperature and CO_2 probes were burned. Infrastructure repairs and replacement parts for warming and MRME, plus labor costs will be covered by UNM insurance. In addition, postfire recovery of nutrient availability, vegetation composition, ANPP, and consumer population dynamics will

occur as part of our normal LTER sampling protocols. However, in response to this externality, we submitted a RAPID proposal to address some key hypotheses based on pre-fire background data related to fire effects on (1) plant-microbial coupling, (2) carbon fluxes during postfire succession, and (3) seasonal and interannual dynamics of consumer-ANPP linkages.

The second event was our mid-funding site visit. Materials associated with that site visit can be found at: http://tierra.unm.edu/.

Publications and grants.
In 2009, Sevilleta LTER scientists have published 2 book chapters and 16 peer reviewed journal articles thus far with 7 more currently in press and several more manuscripts currently in review.

The following four grants were awarded in 2009:
"Collaborative research: Dynamics of plant-soil interactions in a changing environment." K.N. Suding, A. Porras-Alfaro, R.L. Sinsabaugh. NSF, 1/1/10 – 1/1/13. **$258,507.**

"Roots with a view: the eukaryotic microbial metatranscriptome of blue grama grass rhizosphere soils shows the way to transformational lignocellulose degrading technologies and elucidates carbon flux through aridland ecosystems." A.J. Powell, B. Simmons, D.O. Natvig, S.L. Collins, R.L. Sinsabaugh, A. Porras-Alfaro, D. Martinez, C. Detter, R.A. Dean, J. Magnuson, R. Berka. DOE Joint Genome Institute, Community Sequencing Program, 600 MB of sequencing, Jan 2010 – Jan 2011.

"Chemical and microbial mechanisms linking litter quality and decomposition rate." K. Treseder, R.L. Sinsabaugh, D.L. Moorhead. NSF EaGER, 10/1/09 – 10/1/11. **$300,000.**

"Hydraulic mechanisms of survival and mortality during drought in piñon-juniper woodlands of southwestern USA." W.T. Pockman, DOE-PER, 3/15/09-3/14/14. **$2,319,408.**

INFORMATION MANAGEMENT

Information management is an integral component of the Sevilleta LTER. The primary goal of the Sevilleta Information Management System (SIMS) is to support site and network research by 1) facilitating access and usability of data and metadata by LTER scientists and the public, and 2) ensuring data integrity and security for future generations.

I. SIMS Implementation and Design

1. Scope and Access: The Sevilleta database is extensive, encompassing tabular and spatial data and metadata from 1988 to the present. As specified in the *LTER Network Data Access Policy*, data and metadata generated by Sevilleta researchers are placed online within two years of data collection. Exceptions are made for imagery of a proprietary nature, data with quality assurance issues, and data collected by graduate students, which are made public only after the student publishes. Data sets too large to be stored online are accessible by ftp upon request. Sevilleta online information resources also include an up-to-date list of Sevilleta publications and archives of photographs, presentations, and reports.

2. Infrastructure: We acquired two SunFire X4140 servers in 2008 to reduce the burden on the nine-year-old SUN Enterprise 450 server which had previously housed the Sevilleta web, database and email servers and most data. One of the new servers is now the database and web server, while the other one provides email. The speed of our website has increased dramatically since it was migrated to the new server. More details about Sevilleta infrastructure are available online at http://tierra.unm.edu/simsitinfrastructure.

3. Database: Several mechanisms are employed to collect and enter data into the Sevilleta database. Approximately half of the data collected by Sevilleta staff are entered into MS Excel on handheld computers at the point of collection in the field, and these data are QA/QC'ed and entered into our MySQL database using a series of Perl scripts. Meteorological data and data collected from sensor networks are transmitted via the wireless network to a server at the Field Station, from which they are harvested every night and inserted in to the MySQL database.

Most Sevilleta tabular data are archived as ASCII text files which can be directly downloaded from the website. For some data sets, query tools that interact directly with MySQL have been developed that will allow users to download a subset of the data from the web page as either text or Excel files. For instance, climate data through the previous day can be downloaded from one of our twelve meteorological stations. (http://tierra.unm.edu/projectdetails?id=SEV001).

Metadata are developed in compliance with EML, the LTER Network standard. All metadata are sufficiently detailed and can be considered of the highest level of "completeness" as defined in the 2004 document *EML Best Practices for LTER Sites* (http://intranet.lternet.edu/im/im_practices/metadata/guides).

4. Personnel: Sevilleta supports approximately 4 FTE's, either from base LTER funding or through UNM's Sevilleta Infrastructure Support account, who comprise the IM Team. The information manager, Kristin Vanderbilt, devotes 90% of her time to day-to-day IM duties and coordinating information management activities among the rest of the IM Team. Doug Moore spends 75% of his time managing climate data, and the system administrator, Renee Brown, divides her time between supporting the LTER and the Sevilleta Field Research Station, which co-funds her position. A permanent four-person field crew allocates 50% of their time to assisting the data manager with data entry, QA/QC, and updating metadata for core long-term studies. A quarter-time GIS Specialist manages spatial data resources, and a quarter-time student programmer helps the information manager develop data entry and QA/QC applications.

5. Web Page: The Sevilleta web page is in a state of transition. The web page at (http://sev.lternet.edu) is no longer being updated, while the new web page (http://tierra.unm.edu) is not yet completely populated. The new website complies with the *Guidelines for LTER Web Site Design and Content*. The new web page is implemented in Drupal, a content management system, which offers new possibilities for data discovery. Drupal has a system of taxonomies (lists of keywords for themes and sites, for instance) and each information product (dataset, publication, image) can be tagged with these keywords, facilitating queries for related information. For instance, if two datasets are tagged with the same site name, then a search on that site name will turn up co-located research projects. The capability of Drupal to integrate content provides a powerful data discovery mechanism to the users of our web page.

Adoption of a standard set of keywords will be essential to the success of this system, and the Sevilleta has selected 260 keywords from the NBII Biodiversity Thesaurus to serve as the core keyword group. This list of keywords may be augmented by additional keywords from the standard LTER Keyword list that is presently under development by the LTER IM Committee.

6. Documentation: The Information Management Handbook, implemented as a Wiki (http://tierra.unm.edu/wikis/im/index.php/Main_Page), contains documentation regarding collection, processing, and archiving Sevilleta's core long-term data sets. All members of the IM Team update this wiki as necessary.

7. Review of SIMS: The IM Team is making progress toward addressing recommendations from previous site reviews. Concerns about server security have been resolved with the installation of a firewall. A new backup system has been purchased to replace the previous inadequate, borrowed system. Scalability of SIMS is addressed with greater use of the relational database MySQL.

SIMS Support for Site, Network, and Community Science

1. Integration with Site Science: The information manager contacts scientists as they initiate research at the Sevilleta to make them aware of data release policies and the procedures for submitting data and metadata. Acquiring data and metadata and quality assuring the data from non-staff researchers is typically an iterative process that eventually yields high quality products that can be released to the public. The Information Manager works closely with the field crew to ensure that Sevilleta long-term data sets are entered, quality assured, and archived in a timely manner.

2. Policies: Data access is tracked in accordance with the LTER Network Data Access Policy. Before a data download can be initiated, a data user must agree to abide by the SEV Data Access Policy (http://sev.lternet.edu/documents/dm/index.html) and to register with their name, address, and affiliation (academic, K-12, etc.). Once registered, a user may download all data sets of interest to them.

3. Metadata and Data Quality: Sevilleta has completed the task of transforming years of legacy semi-structured text metadata in to Level 5 compliant EML, as specified in the *EML Best Practices for LTER Sites* (2004). This was a tedious and time-consuming experience that involved reformatting all of the old metadata and running Perl scripts to generate EML that often still had to be tweaked by hand. A MS Access application was developed that facilitated this project and also entered the metadata in to a SQL Server 2000 database located at the LTER Network Office.

Rigorous QA/QC methods are applied to data collected by the Sevilleta field crew. Perl and SAS scripts are used to identify incorrect codes, out-of-range values, and other anomalies in the data. Non-staff researchers QA/QC their own data; the information manager ensures that no inconsistencies exist between data and metadata prior to archival.

For the sensor data that is inserted daily into the MySQL database, out-of-range values are flagged as the data are entered. If records indicate that the sensor is malfunctioning, then data

values collected during the problem period are also automatically flagged as incorrect. Graphs of sensor data are available on the Sevilleta website to help researchers detect when sensors are malfunctioning:
(http://sev.lternet.edu/data/search/warming/temperature/plot.php?plot=soiltemp&period=weekly.

4. Contribution to LTER Network and Other Activities: Sevilleta updates meteorology data in the cross-site ClimDB database on a weekly basis. Cross-site personnel, site, and publication databases are updated at least twice a year. Sevilleta EML is harvested once a week and resides in the LNO Metacat.

Education, Outreach, Cross-site and Network Level Activities.
The SEV LTER continues its activity involvement in education and outreach through BEMP (our Schoolyard LTER), the SNWR, E-MRGE (our GK-12 program), our REU Sites program, ESA SEEDS, and our everyday classroom teaching activities. SEV scientists are also active in numerous cross-site and synthesis projects, and provide service to the LTER Network.

Schoolyard LTER.
The Sevilleta schoolyard LTER/Bosque Ecosystem Monitoring Program (BEMP) is dedicated to science, education, and stewardship, bringing together each year over 2,000 K-12 students, their teachers, and UNM researchers to monitor and understand the Rio Grande and its riverside "bosque" forest. BEMP is coordinated by Mr. Dan Shaw, Biology Teacher at the Bosque School, and by Cliff Crawford (Professor Emeritus, UNM Biology) and Kim Eichhorst (BEMP Science Education and Information Specialist), and Jen Schuetz, Program Administrator. Currently, BEMP organizes field and classroom activities at a variety of sites along the Middle Rio Grande in collaboration with more than 20 school systems, including the Albuquerque Public Schools, local private schools, one home school, several rural schools and two Pueblo schools. Each month, students use research sites spanning 250 km of the Rio Grande to gather key indicators of structural and functional change within this complex ecosystem. These data are published in reports and used by local, state, tribal, and federal governmental agencies.

Most BEMP students are from traditionally underrepresented groups in environmental education including large numbers of Hispanics and Native Americans. BEMP sponsors an upper level undergraduate/graduate biology class at UNM in which students from the sciences, education, communication, and other departments learn about the bosque ecosystem while serving as interns within the program. The interns act as liaisons between researchers and K-12 students, take on quality control duties, assist in field data collection, lab analyses, and are mentors to the K-12 students. BEMP activities meet national and state education standards for K-12 science, math, social studies, and also include lessons in art and language, as well.

Through a variety of funding sources, including core and supplemental NSF LTER support, BEMP staff coordinate field activities and design in-class exercises and materials, including a lending library of lesson plans and activity kits that BEMP interns and teachers can readily use with K-12 students. In addition, a professional educator works with BEMP staff to develop and present classroom activities in the context of ongoing bosque science. All activities are translated into Spanish and placed on the BEMP website (http://www.bosqueschool.org/BEMP/bemp.htm) as both a service to existing BEMP classrooms and as a recruitment and expansion tool.

Undergraduate education. UNM is a certified Hispanic serving institution, and the Department of Biology has over 1200 undergraduate majors of which 48% are Caucasian, 33% Hispanic, 10% Native American, 7% Asian and 2% Black. Thus, through our day-to-day activities UNM faculty regularly work with, encourage, mentor, and train a large number of minority students. In that regard, we serve the broader goal of recruiting minority students into ecological research.

In 1996, ESA established SEEDS (Strategies for Ecology Education, Development and Sustainability) to diversify and advance the profession of ecology. A key goal is to stimulate and nurture the interest of underrepresented students in ecological research. In 2005, UNM Biology established a local SEEDS Chapter (Collins is faculty rep). In November 2006, Sevilleta hosted a national SEEDS field trip and career forum. In September 2008 the Sevilleta LTER hosted a research visit and career forum for the SEEDS chapters at NAU and UTEP. In addition, in February 2009, the Sevilleta LTER hosted the annual SEEDS Leadership Conference.

Sevilleta REU Program.
Samantha Adelberg, Brown University. Geomicrobiology of the Sevilleta wells and springs: Predicting the metabolic energy available to microorganisms.

The semiarid Southwest, where rainfall is scare and rivers are few, groundwater wells and springs provide a vital source of water to all forms of life. However, despite the incredibly important role groundwater plays in this environment, there is a minimal understanding of the aqueous geochemistry and microbiology of these small desert oases. This study conducted a comprehensive survey of the hydrochemical composition of nearly 20 wells and springs in the Sevilleta National Wildlife Refuge (NWR) and surrounding area. We measured pH, temperature, conductivity, DO, and TDS in the field, and major, minor, and trace elements, Cl/Br ratios, ^{18}O, D, $d^{13}C$. Using geochemical modeling (PHREEQC) and basic thermodynamics we focused on 6 springs and wells with contrasting geology to predict the chemical reactions that could potentially occur in these waters as well as the metabolic energy available to any microorganism that facilitates one of these reactions. Preliminary evaluations reveal that

potential reactions and accompanying affinity coefficients change significantly within the refuge due to the unique tectonic structure of the rift valley. Additionally, while the local geology influences the surrounding natural systems and thus water chemistry, the microorganisms that live in each system can manipulate the water quality as well, further creating distinct microenvironments within the Sevilleta NWR. This method of evaluation alone cannot confirm the existence of certain microorganisms; however, by combining thermodynamics with geochemical analyses we can create a thermodynamic model that predicts how and why microbial diversity differs as well as provide reliable information for future geomicrobiology research.

Cesar Coronado, Northern New Mexico University. Comparison of noninvasive sampling techniques for coyotes: Hair snares vs. scat surveys.

Reliable survey methods are important to managers when they make decisions regarding predator population conservation and management. Traditional methods, such as direct counts, are less useful due to the elusive and nocturnal behavior of mammalian predators. Furthermore, human activity can have significant impacts on predator movements and abundance. In this study we focused on the coyote (*Canis latrans*), which is a top predator at the Sevilleta National Wildlife Refuge (NWR) in central New Mexico. We compared success rates of two non-invasive survey techniques; scat surveys on roads and hair snares near roads. In addition, we considered how human activity (road use) affects coyote density and the success of these two non-invasive survey techniques. Scat and hair snare surveys were completed on a weekly basis. Weekly scat counts were used to assess relative coyote density and hair snares were considered successful if hair was found. Results suggest that the type of scent lure used impacts hair snare success and that scat surveys were more successful than the hair snares. Furthermore, road use does appear to have a negative impact on both coyote density and the success of both survey techniques.

Albert Davila, Jr., Oberlin College. Chihuahuan Desert lizard abundance in Gunnison's prairie dog habitat: Do lizards prefer prairie dog colonies?

Burrowing rodents, such as Gunnison's prairie dogs (*Cynomys gunnisoni*), have been thought of as keystone species that provide suitable habitats for a number of other species. Shrubs also play a key role in the creation of suitable habitats especially for small animals that need to thermo regulate. Chihuahuan Desert lizards that live in areas inhabited with prairie dogs were the main focus of the study. Three lizards were observed during the study, the New Mexico whiptail (*Cnemidophorus neomexicanus*), the little striped whiptail (*Cnemidophorus inornatus*), and the lesser earless lizard (*Holbrookia maculata*). Six one hundred and fifty meter transects that ran through an area with prairie dog mounds and six other transects that ran through an area with similar terrain but did not have any prairie dog mounds were used for observation. To understand

the use of the terrain by the lizards and how lizard population densities are affected, shrub measurements were also taken along the transects to measure their densities on the plots.

Lizard population densities of the three plots that contained prairie dog mounds were compared to the population densities of the three plots that did not contain any mounds. It appears that population densities are greater on the plots with mounds then without. It also appears that a plot with a lot of mounds but low shrub density had few lizards then a plot with numerous mounds and high shrub density. These results are consistent with the conclusion that prairie dogs and shrubs play an important role in forming suitable habitats for animals such as Chihuahuan Desert Lizards.

Giomara La Quay, University of Metropolitana, Puerto Rico. Soil nitrogen and physical properties of the Los Pinos Mountains, New Mexico.

Soil and plants have a very close relationship, as they are strongly influenced by each other, and this complex relationship has always been of great interest to the ecological community. Soil is one of the more important factors for plants, as they show dependence for anchorage, water and nutrients. The different factors that are responsible for soil composition and nitrogen dynamics are unique in arid and semi-arid ecosystems. There is little know about this soil dynamics and what role they play in the Los Pinos Mountains, part of the Sevilleta Wildlife Refuge, New Mexico, where the study takes place. The study was conducted during the months of June and July of 2009, with the objective to answering the question of how the concentrations of total nitrogen (inorganic N) are related to abiotic and biotic factors. These factors being, soil moisture, temperature, and texture by aspect and elevation and the influence of vegetation. Two sites with similar topography and elevation were chosen within Los Pinos Mountains (Southern most and Northern most). Each site consisted of 32 points arranged by elevation, 16 in north facing slopes, and the same amount in south facing slopes, for a total of 62 points. In these points soil samples for measuring soil moisture and texture were taken and ion exchange resin bags were used to measure total nitrogen, these were place under Pinion (*Pinus edulis*), Juniper (*Juniperus monosperma*), grass (including blue and black grama) and bare spaces (an area greater than 30x30 cm). The north faces in general showed greater moisture than the south face as expected, being that the average temperature it's also highest in the south site. There was more moisture under canopy than bare spaces. For nitrogen there is expected to be a higher concentration under Juniper than Pinion, and bare should have the lowest concentration.

Lian Liu, University of Michigan. A comparative study of water quality and aquatic macroinvertebrate diversity in the Rio Grande and its ditches.

Water quality in the Rio Grande and its neighboring ditch was assessed by sampling for the aquatic macroinvertebrates in both bodies of water. Sites were chosen according to their similarities in vegetation and three different types of vegetation were selected: willow, salt cedar, and Russian olive. The area that macroinvertebrates were sampled from was standardized using a throw trap. In addition, a water sample was taken to assess phosphate (PO4) and nitrate (NO3) levels. All collected macroinvertebrates were identified to family, genus, or species. ANOVA and regression were used to assess the relationship between site type, vegetation type, flow, water depth, nitrate and phosphate levels, taxonomic richness, and invertebrate abundance. In general more pollution tolerant taxa were found in the ditch than in the river. The ditch also had higher abundance in the number of macroinvertebrates than the river. Diversity was generally lower in salt cedar vegetated sites than in willow or Russian olive vegetated sites, which were similar. Higher flow and greater depth was associated with low abundance and richness. There was no significant relationship between phosphate or nitrate levels and either abundance or richness. These results indicate that the river and the ditch contained two different communities of macroinvertebrates, although there is some overlap between the two communities. Future work could focus on physicochemical parameters and precipitation and their affect on the invertebrate community.

Amanda Martinez, Brigham Young University. Aquatic invertebrate diversity in springs and wells on the Sevilleta.

Although, water is a limiting factor in arid ecosystems, there are 25 known wells and springs on the Sevilleta National Wildlife Refuge that provide a reliable source of water for wildlife. The source of the spring or well water can greatly influence the chemistry of the water. The sources of the water also influence the aquatic invertebrates that can be found living in them. This research addressed three questions: Is the aquatic invertebrate diversity significantly different between the man made wells and the naturally occurring springs? How does diversity correlate with water chemistry? Are the insects found in the Rio Grande and nearby ditches similar to those found in the wells and springs? I sampled from seven wells and four springs on the Sevilleta hoping to answer these intriguing questions.

Maxine Paul, Columbia University. Quantifying biome specific relationships and monsoon event responses using LAI (leaf area index), NDVI (normalized difference vegetation index) PRI (photochemical radiation index) in grassland and shrubland ecosystems at the Sevilleta.

The overall goal of this research is to collect and compare datasets from ground-based methods and remote sensing methods in order to better understand how well the satellite datasets capture physiological activity of shrubs and grasses during the monsoon season in specific biomes. This research was focused this comparison on two widespread biomes on the Sevilleta National Wildlife Refuge, desert grassland and desert shrubland. The grassland biome is dominated by Blue Grama (*Bouteloua gracilis*) and Black Grama (*Bouteloua eriopoda*), while the shrubland is dominated by the native invasive Creosote (*Larrea tridentata*).

Plant biomass production is related to absorbed light, which is determined by leaf area. NDVI and PRI estimate reflectance characteristics of vegetation and are used as a proxy for changes in photosynthesis and LAI over time. With three 100m transects at each site, I measured LAI, NDVI, and PRI at small scale plots (less than 1 square meter)(n=30) in roughly weekly intervals in June and July 2009. These values have been compared to NDVI, PRI and net ecosystem exchange of carbon measured continuously on top of a 3m tripod in each biome. I used a portable NDVI/PRI sensor built by Dr. Lee Vierling from Idaho State University, and a Decagon PAR/LAI ceptometer (<1 square m scale) for the small plot measurements. Net ecosystem exchange of carbon was measured by the eddy covariance flux towers run by Litvak's group continuously since 2007. With this data I report on trends over the months of June and July in all these factors to understand changes at the beginning of the monsoon season, specific to the arid grassland and shrubland biomes. Finally, a comparison of methods to quantify LAI in these biomes will be discussed. The results will help quantify the understanding of the relationship between these variables and contribute to future methods of understanding plant biomass production. In future work with the Litvak lab, we will go on to assess the relationship between ground measurements and remote sensing (satellite NDVI values).

Amanda Schaupp, Allegheny College. The effect of arthropods on *Dipodomys spectabilis* food stores and storing behavior.

Banner-tailed kangaroo rats (*Dipodomys spectabilis*) cut upper stems of the plant *Sporobolus cryptandrus* into small sections that they store in their cheeks. In their mound these seed stems are pushed out of their cheeks and placed vertically against the side of the den. Most of these stems are bundled together into tight packs of 50 or more stems. Two trials were done at seven active and seven inactive to see if placement of these stems vertically helps to reduce the amount of seeds pilfered by arthropods. In active dens when comparing orientation of seeds with pilfering by arthropods vertically orientated seeds were taken the least, followed by horizontal, and then scattered, although these were non-significant. In inactive mounds there was no preference shown by orientation of seed stems. When comparing the first trial to the second trial a higher percentage of seed stems were taken and this is most likely due to the arthropods learning of these locations and zoning into this area. Pilfering by arthropods is not the only reason for this behavior other possibilities could include fungal growth and mating interactions.

Hayley Stansell, North Carolina State University. Mapping the landscape of fear for Gunnison's prairie dogs.

When determining the effective quality of a habitat to a species of animal, one factor that is perhaps overlooked is the degree of safety from predation a habitat can offer. On a small scale, landscape features affect a forager's perception of predation risk, be they shrubs, manmade structures, or in the case of prairie dogs –burrow entrances. In order to examine the importance of such features, I isolated and spatially mapped the predation cost of foraging for a relatively dense colony of Gunnison's prairie dogs located on the Sevilleta National Wildlife Refuge, New Mexico. This was done using a grid of experimental food patches, which were laid over a large portion of the colony in order to measure giving up densities on a fine scale over the landscape. The resulting contour map of predation risk constitutes the animals' "landscape of fear" and reveals information as to which structures most strongly affect prairie dogs' sense of security. It appears that proximity to burrows is key, but it is possible that presence of vegetation, which interrupts lines of sight, plays a role as well. There is also the possibility that vegetation may affect burrow placement. Thus, further study conducted in greater detail and over a larger time scale may provide more insight into the interrelatedness of burrow placement, vegetation, and predation risk.

Francisco "Frankie" Reyes, University of Texas – El Paso. A salinization study within the San Acacia Region, Sevilleta NWR, NM.

Water management and the scarcity of water is a considerable concern in the American Southwest. The quality of ground and surface waters is carefully monitored due to the shortage of renewable water supplies in the region and specifically in the Rio Grande rift corridor. Both high salinity and elevated trace element concentrations are regionally important in impairing water quality, and identifying sources of these contaminants remains an ongoing challenge. It has been hypothesized that deep-seated faults within the rift provide conduits for the ascent of deeply derived fluids, while others have proposed the hypothesis that upwelling sedimentary basin brines at interbasin constrictions represent a significant salinity input to the modern Rio Grande.

The purpose of this study is to test and refine existing models for Rio Grande salinization using analog studies of similar rift springs while reevaluating the influence of the underlying Socorro Magma Body (SMB). We used aqueous geochemical techniques (field parameters, major and trace elements, Cl/Br ratios, δ18O and δD) and geochemical modeling to identify salinity components in the middle Rio Grande basin (MRGB). An integrated study of spring geochemistry with factors related to poor water quality will allow for an improved comprehension of natural contaminants in the Rio Grande hydrochemical system.

The Rio Salado Box (RSB) and San Acacia springs, both located adjacent to the Sevilleta National Wildlife Refuge in central NM, have been identified as major salinity inputs in the MRGB. San Acacia contains the highest salinity concentrations of all Sevilleta NWR waters, and it is observed to influence the nearby canals and the Rio Grande by increasing the river salinity. The resulting irrigation water can lower crop yields and is unhealthy for livestock and wildlife, sometimes exceeding EPA guidelines. Major ion, stable isotope and trace element analysis suggest that the brine pool has evolved from evaporative concentration, but that the source springs are chemically similar to the RSB waters, which are established as deeply derived fluids sourcing from the Jeter fault. Rift-bounding and intrarift basement penetrating faults can provide "fast paths" for the ascent of these Cl-rich fluids, which may be related to degassing from the SMB.

Andrea Westerband, SUNY College of Environmental Science and Forestry. Effects of aspect and elevation on the distribution of Pinyon Pine and Juniper trees, along with index of grass density within the Los Pinos Mountains, New Mexico.

The concept of abiotic effects on the distribution of vegetation has been of interest to the scientific community, and has been studied among numerous long-term ecological research (LTER) stations across the United States. The Los Pinos Mountains within the Sevilleta National Wildlife Refuge, New Mexico, are dominated by a pinyon-juniper woodland and exhibit sufficient differences in microclimate, from one region to the next, to allow a study of the distribution of vegetation types. The study, conducted during the summer months of June and July, aimed to answer the question of whether or not different factors played a role in the abundance and/or percent cover of *Pinus edulis*, *Juniperus monosperma* and grass (including blue and black grama). It was hypothesized that the south face was markedly drier due to a higher amount of incoming solar radiation. This concept has been discussed in related research. For the purposes of this study flowering was used an index of productivity. Principle independent variables include: site location (north end of the mountain range versus the southern end), aspect and elevation. Two areas of similar topography and elevation were chosen within each site and multiple vegetation transects were laid out in order to quantify how many individuals occurred and how much space they occupied. Grass density was also tabulated using small plots laid out along each transect. Key results include: a significant difference in the percent cover of both tree species explained by aspect, a significant difference in the amount of individuals encountered for each face, a significant difference in the number of individuals found per site, difference in the amount of individuals flowering in relation to the aspect, and a difference in the type of species that was predominant on each face. Statistical tests carried out included a logistic test and ANOVA. Based on the results it may be concluded that there are climactic differences within different areas of the Los Pinos Mountains, predominantly the north and south face, which could be further explained by measures of soil water content, ambient temperature, soil nutrients and total incoming solar radiation.

IV. K-12 Outreach. In 2006 we started E-MRGE, our GK-12 program in Ecohydrogeology in the Middle Rio Grande Environment (PI Collins, Co-PI, Laura Crossey - Dept. Earth and Planetary Sciences). E-MRGE Fellows work in partnership with middle school teachers in three rural New Mexico communities (Belen, Socorro and Laguna Pueblo) and the SNWR outreach program. Fellows and teachers develop activities to learn about long-term research and then develop related inquiry-based projects that provide hands-on science experiences for middle school students. These active learning projects are designed to meet New Mexico science standards. Several of our GK12 Fellows are also conducting part or all of their dissertation research at the Sevilleta.

In July of 2009 12 middle school students from our three GK12 schools attended a week-long summer internship at the Sevilleta National Wildlife Refuge organized by Sevilleta LTER graduate student and GK12 Fellow Jason Thomas. Participants included other GK12 Fellows and participating middle school teachers. Students participated in data collection and instruction in botanical illustration, sedimentary geology, orienteering and topographic maps, bird netting,

lizard capture, arthropod pitfall traps, small mammal trapping, plant identification and Sevilleta plant communities, and volcanic geology. The middle school students also had dinner with and interacted with our summer REU students.

In Summer 2009 we received a Research Experience for Teacher supplement from NSF for Ms. Theresa Apodaca, a middle school science teacher at Sarracino Middle School in Socorro, NM. Theresa is participating in a research project under the guidance of Dr. Laura Crossey and in collaboration with Dr. Crossey's graduate student Amy Williams. Amy just won the best student presentation award at the 2008 AGU meetings in San Francisco based on work she did last year at the Sevilleta! Theresa is one of the current Teaching Partners in our E-MRGE GK12 Program directed by Scott Collins and Laura Crossey. Based on our nomination, in December 2008 Theresa awarded the 2008 Outstanding Science Teacher Award from the New Mexico Academy of Sciences. Theresa has been a tireless and enthusiastic participant in our GK12 Program, and we are very pleased to have her working on a research supplement award this year.

The primary goal of Theresa's RET project is to acquire new aqueous geochemical data along targeted reaches of the Rio Grande and from springs located in the Sevilleta National Wildlife Refuge. Both groundwater and surface water are important resources for many metropolitan and agricultural communities along the Rio Grande corridor. High salinity has been identified as regionally important in impairing water quality. Although the river waters are dominated by spring snowmelt and monsoonal rainfall events, recent research has revealed the widespread presence of volumetrically small, but geochemically important groundwater contributions to the river system. These "endogenic" waters have been associated with springs issuing along rift-bounding faults in central New Mexico.

Network-level interactions. At the Network level and beyond, SEV LTER scientists continue to be involved in a variety of cross-site and international projects. The Sevilleta Information Manager (Vanderbilt) has been active in Network level activities. She has served on the Network Information System Advisory Committee (NISAC) since 2007. She has been the Chair of the International LTER Information Management Committee since 2006, and has organized and participated in ILTER IM Workshops in China, Korea, and Taiwan. She is collaborating with other US Information Managers and LTER Network Office personnel to create a series of training videos for new Information Managers, the first of which can be seen at http://www.ilternet.edu/training/training-online-resources-collection. She has also collaborated with Judy Cushing of Evergreen State College and other grasslands LTER information managers on a research project to develop an integrated cross-site ANPP database. She organized an ILTER/LTER workshop in January 2009 that used the database as the basis for a research paper.

PI Collins represents the SEV on the LTER Science Council, and prior to that was an elected member of the LTER Executive Committee. Collins served as PI on the NSF-funded LTER Planning Grant that over a three year period developed an ambitious funding initiative and research agenda for the LTER Network (the LTER Decadal Plan) to increase network-level research coordination, cooperation, collaboration and capability. Finally, Sevilleta researchers are involved in numerous synthesis efforts and networks, such as Chapman conferences, PrecipNet, DireNet, TraitNet, and PDTNet (Clark et al. 2007, Cleland et al. 2008, Collins et al. 2008), and other cross site projects on compensatory dynamics (Houlahan et al. 2007), shrub

encroachment (Knapp et al. 2008), and the international Nutrient Network (NutNet) to name a few. Sevilleta LTER continues to participate in the National Phenology Network.

In an effort to promote cross-site research and communication, the Sevilleta LTER hosted a regional annual symposium with scientists from JOR, CAP, SGS, NWT and KNZ presenting synthesis talks and poster presentations along with breakout groups to coordinate existing and potentially new cross-site research activities. At this cross-site workshop we agreed to hold a multi-site workshop once every three years. Thus, on a three year cycle these sites would hold: one site-based meeting, one regional meeting, and then attend the LTER All Scientists meeting.

SOCIAL-ECOLOGICAL RESEARCH

The Sevilleta LTER Program has not had a social-ecological research component to date, but is currently expanding in that realm via three collaborative efforts:

1. The Sevilleta LTER is part of a five site social sciences funding collaboration (JOR, CAP, SGS, KNZ and SEV), "**Socio-ecological gradients and land use fragmentation: a cross-site comparative analysis."** The objective of this cross-site collaboration is to answer the following research question: *Is the degree of land fragmentation a function of magnitude and/or rate of change of water availability, population growth, and urbanization?* At each site we will investigate the role of these drivers, in addition to other proximate drivers, in the process of land fragmentation.

2. Our 2009 supplement included a request for a related, site based project to be conducted by Mike Agar, Professor Emeritus, University of Maryland, currently a resident of Santa Fe, who is an expert in agent-based modeling. In this research activity Professor Agar will review current literature in ecological anthropology with emphases on the "new ecology," historical ecology, and political ecology. He will then coordinate this background work with relevant work being conducted as part of the five site cross-site project funded in 2007. The problem focus will be land fragmentation, in part because of the ongoing supplement, mentioned above. The focal community for this supplement will be Rio Rancho, a rapidly growing community north and west of Albuquerque, for which Agar is developing a qualitative methodology to document long-term land fragmentation as an outcome of sociocultural processes.

3. The Sevilleta LTER Program is part of a collaborative ULTRA-ex (Urban Long-Term Research Areas) planning proposal with two other LTER Sites, JOR and CAP. Understanding the socio-ecological dynamics of urban areas is limited by inadequate knowledge of the type, quantity, and quality of ecosystem services delivered in metropolitan regions and how actors incorporate considerations of ecosystem services *and* household preferences into management decisions. The principal question of our proposed research is to understand how decision makers respond to and make land and water use decisions based on measured and preferred ecosystem services at the wildland-rural-urban fringe in the arid Southwest. If funded, we will employ a comparative, gradient approach using the metropolitan areas of Las Cruces and Albuquerque, NM and Phoenix, AZ as case studies. Primary methods include stakeholder forums and focus groups with decision makers, hedonic modeling of houses prices and ecosystem service amenities, and biophysical modeling of ecosystem services. This proposal is currently in "purgatory" in that it was not one of the first batch of proposals selected for funding, but NSF is

searching for funds in hopes of making an award. If this planning grant is not funded, we plan to use our ideas as a basis for a Coupled Natural-Human (CNH) proposal to NSF in the near future.

Together these activities illustrate how the Sevilleta LTER and its scientists are committed to (1) conducting cutting edge research, (2) achieving the goals of the LTER Network, (3) expanding the spatial, temporal and conceptual bases of our research through the addition of new participants, and (4) furthering our education, outreach and training efforts at K-12, undergraduate, graduate, postgraduate, and informal levels.

Findings

As noted above, our research program is based on the concept of pulse dynamics in which pulses of rainfall, primarily at the event scale, stimulate biological processes from microbial metabolism through plant production and consumer population dynamics. The main components of our research are climate drivers, water in the environment, biogeochemistry and soils, producer dynamics, and consumer dynamics. Below we present highlights of some of the key results from our research in 2008-2009.

Climate variability (Doug Moore)

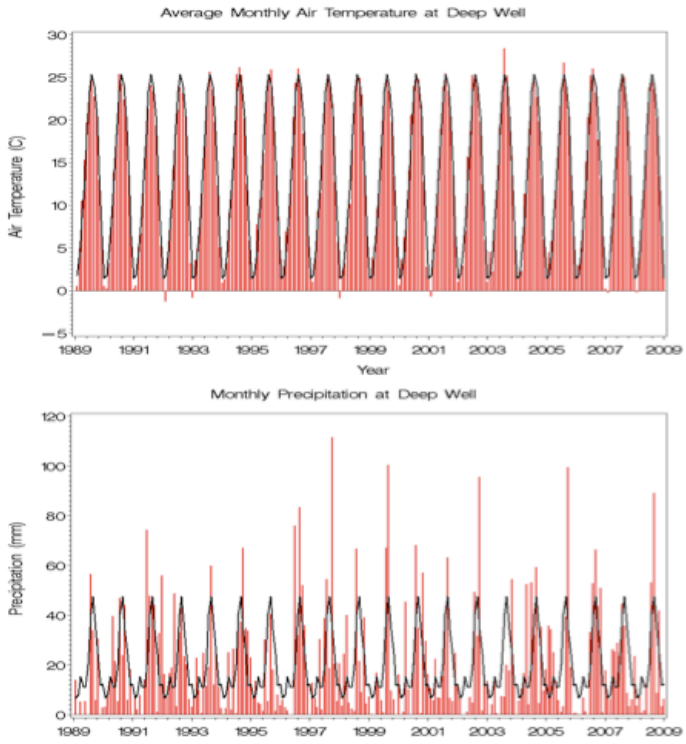


Figure 1. Monthly temperature and precipitation from our Deep Well meteorological station from 1989-present. In general, temperature is highly regular from year to year with rare anomalies. Precipitation, on the other hand, is highly variable. Neither shows any increasing or decreasing trend over the period of record.

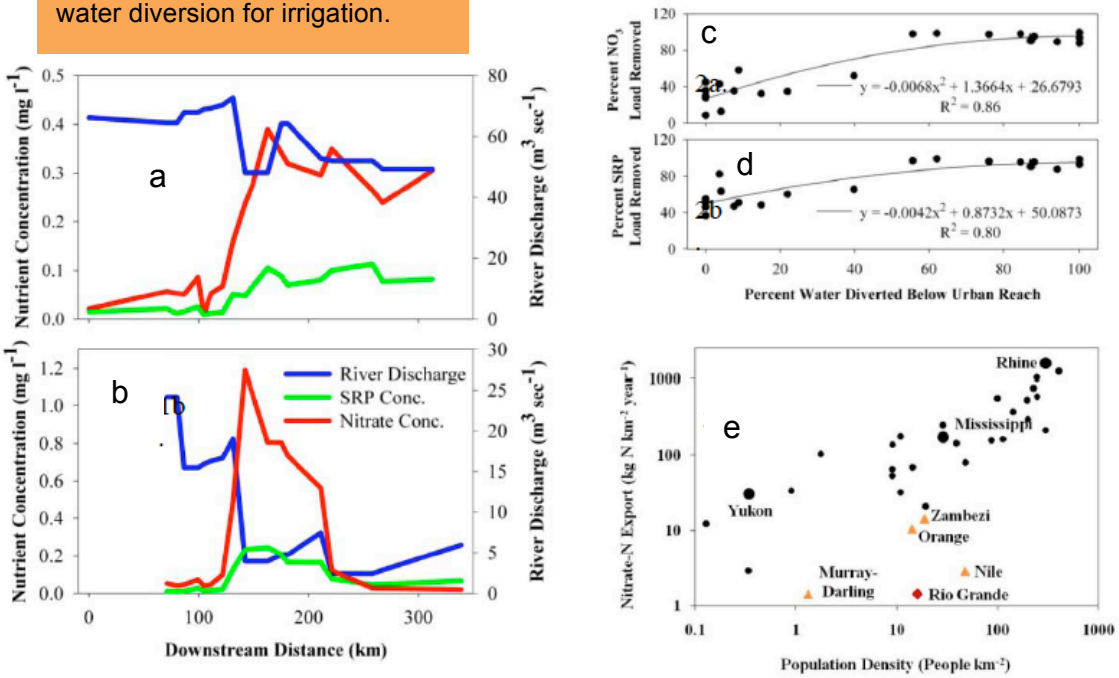
Analysis of the long-term climate record at our main on-site meteorological station, Deep Well, shows the very regulate interannual and seasonal pattern of temperature coupled with the highly variable seasonal and interannual variation in precipitation (Fig 1). For the most part, there are few temperature anomalies and those that occur tend to be during the summer. However, there are many precipitation anomalies over the 20 year record at Deep Well and these anomalies occur in both monsoon and non-monsoon seasons. Overall, the data suggest no change in mean precipitation or temperature over the previous 20 years, but an increase in precipitation variability during the summer monsoon.

Water and ecophysiology

Rio Grande water quality (Dave Van Horn and Cliff Dahm). To determine anthropogenic impacts on nutrient loading and retention in an arid land river ecosystem, Sevilleta graduate student Dave Van Horn collected samples once a month for 28 months at 30 sites along the 340 km Middle Rio Grande (MRG). During 15 months he also collected samples from all of the major tributaries to the MRG. Samples were analyzed for inorganic nutrients, and discharge data from 24 river and irrigation return flow gauges and four wastewater treatment plants were used to calculate nutrient loads. Water entering the MRG from upstream contained low concentrations and loads of NO3, SRP,

and NH4 (Fig 2a,b). During all months the Albuquerque wastewater treatment plant was the major contributor of inorganic nutrients to the MRG, resulting in instream concentration and load increases of ~2000% for NO3 and SRP. During months when little water was diverted from the MRG for irrigation, nutrient levels remained elevated for ~260 km below the wastewater inputs (Fig 2a). During months when significant portions of the river flow were diverted for irrigation, NO3 and SRP concentrations and loads declined dramatically in the downstream direction (Fig 2b). Total retention of wastewater inputs within the MRG corridor ranged from 18 to 99% and 34 to 99% for NO3 and SRP, respectively, with a strong and significant relationship found between the percentage of water diverted from the MRG for irrigation, and the percentage of NO3 (r2= 0.86) and SRP (r2= 0.80) removed within the reach (Fig 2c,d). These results indicate the MRG agricultural network acts as a nutrient sink. Nitrogen export as a function of population density from the MRG was significantly lower than that of mesic systems but was comparable to export from other arid land rivers (Fig 2e). Irrigation associated water losses averaged 62% of incoming water, highlighting that the important ecosystem service of nutrient retention provided by the MRG irrigation network comes with the expense of significant water loss.

Figure 2. Changes in nutrient loading in the Middle Rio Grande during periods with and without water diversion for irrigation.



Rio Grande Bosque evapotranspiration (James Cleverly, Jim Thibault, Cliff Dahm). Measurements of evapotranspiration (ET, via eddy flux towers) and water table (WT) depths beginning in 1999 have occurred at several Rio Grande riparian sites within, upstream, and downstream of the Sevilleta NWR. Sites include a cottonwood-dominated site near Albuquerque (CW), a xeroriparian saltcedar site within the Sevilleta (SCX), a young Russian olive and willow site in La Joya State Game Refuge (ROW), and a dense, monotypic saltcedar site at Bosque del Apache NWR (SCM). ROW and SCM are subject to flooding during episodes of high river flows. Climate conditions ranged from very wet

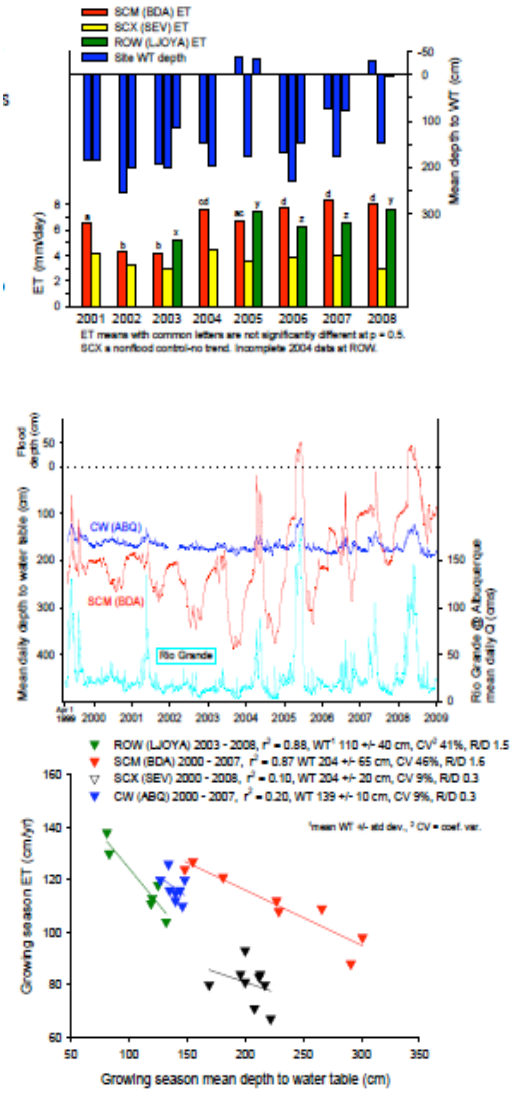


Figure 3. ET, mean depth to water table and the relationshiop bwtween ET and depth to water table at four riparian sites along the Middle Rio Grande.

to extreme drought (Palmer Hydrological Drought Index), affecting river flows. In particular, many spring runoff periods (Apr.-Jun., Fig 3a) were well below normal, although spring flows 149-183% of normal occurred in 2005 & 2008. WTs ranged from ~4 m depth to flood stage and fluctuated dramatically at ROW and SCM, but were greatly dampened at CW and SCX, likely affected by nearby irrigation controls and municipal return flows (Fig 3b).

Within each site, total growing season ET declined with deeper mean WTs, with strong correlations at ROW and SCM (Fig 3c), especially in years with wider ranging WT depths. Mean growing season ranges of 1.6-2.3 m and range-to-depth ratios (R/D) of 1.5-1.6 occurred at these sites, vs. 0.5-0.6 m and 0.3 R/D at CW and SCX. In these mixed-phreatophyte communities, dynamic WTs, which expose a greater extent of the vadose zone throughout the growing season, may play a more important role than depth itself on transpiration rates.

Spring snowmelt floods tend to be greater in magnitude and duration than flashier summer monsoonal floods. To examine the effect of flooding on ET, we compared daily ET rates within sites during each year's historic spring runoff period (1 May-15 June). Complete inundation occurred over the entire period at SCM in 2005 and 2008, and in 2005 at ROW, which was inundated or saturated in 2008. At ROW, ET increased significantly in flood years vs. dry years. While ET has increased over the last few wetter springs at SCM, it was not significantly different from ET in some nonflooding conditions, including the drought in 2006. ET was not related to ambient mean minimum spring temperatures. Structural and phenological differences between young, emerging mixed stands and mature, dense saltcedar sites may affect evaporation and transpiration during spring flooding.

Ecophysiology of piñon and juniper in response to prolonged drought. (Judd Hill, Rob Pangle, Jen Plaut, Will Pockman, Nate McDowell, Enrico Yapez). Long-term climate models predict that southwestern North America will become drier and warmer in the coming decades. Piñon pine (*Pinus edulis*) and juniper (*Juniperus monosperma*) woodlands are the dominant forests in the semi-arid regions of the Southwest, where some areas had almost 100% piñon mortality in the summer of 2003. To determine the

specific mechanisms leading to widespread piñon mortality, we established a long-term rainfall manipulation experiment in piñon-juniper woodland at the Sevilleta. The experiment has 12 plots, each 1600 m^2. Four different experimental treatments are each replicated in three blocks. Blocks are differentiated by slope and aspect (S facing and N

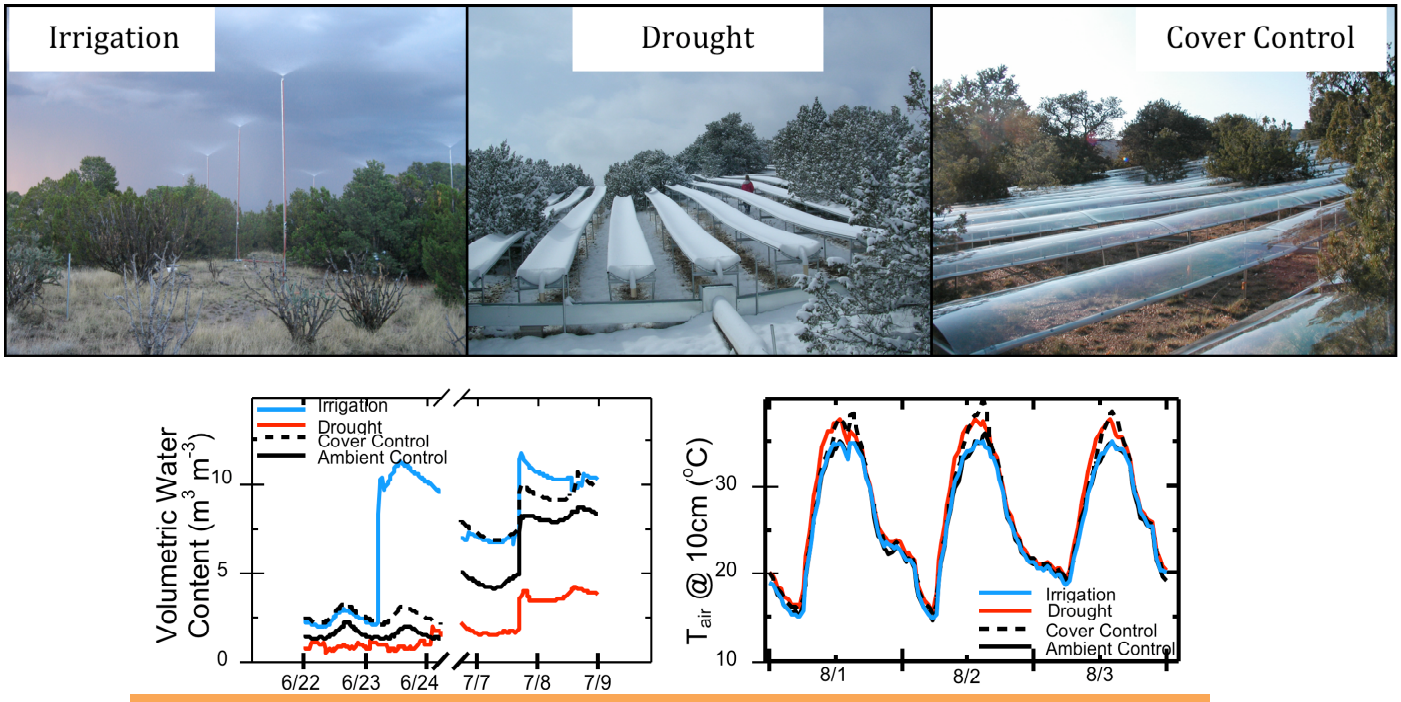


Figure 4. Effect of experimental drought and irrigation on soil volume water content and air temperature. Above are photographs of the treatment infrastructure.

facing slopes, and flat ground). Treatments include: 1) ambient control plots, 2) irrigation plots capable of supplementing 20mm of rain, 3) drought plots which remove 45% of natural precipitation, and 4) cover control plots that have a similar design to the drought treatment, but do not remove precipitation from the plot. An additional 40 piñon trees have been sprayed to prevent attack from *Ips* (pine bark beetle).

Five piñon and five juniper target trees are monitored and instrumented within each plot. Approximately 1300 sensors measuring microclimate and tree physiological characteristics record data every 15 minutes throughout the experiment (~125k automated observations/day). Periodic (~monthly) measurements are made for plant water potential; non structural carbohydrates (NSC); allometric characteristics of twigs and stems; leaf, stem, and soil gas exchange; litter production; nutrient (N) cycling; insect activity. Supplemental irrigation events significantly increase soil water; drought treatments decrease water (Fig 4a,b).

As noted above, portions of the southwestern USA experienced an estimated 40 to 95% mortality of piñon pine (*Pinus edulis*) and 2-25% mortality of juniper (*Juniperus monosperma*) during a recent prolonged drought (1998-2004). This mortality has significantly decreased woody plant cover and altered species distributions throughout the region. The prevailing mechanisms driving drought-induced mortality involve xylem

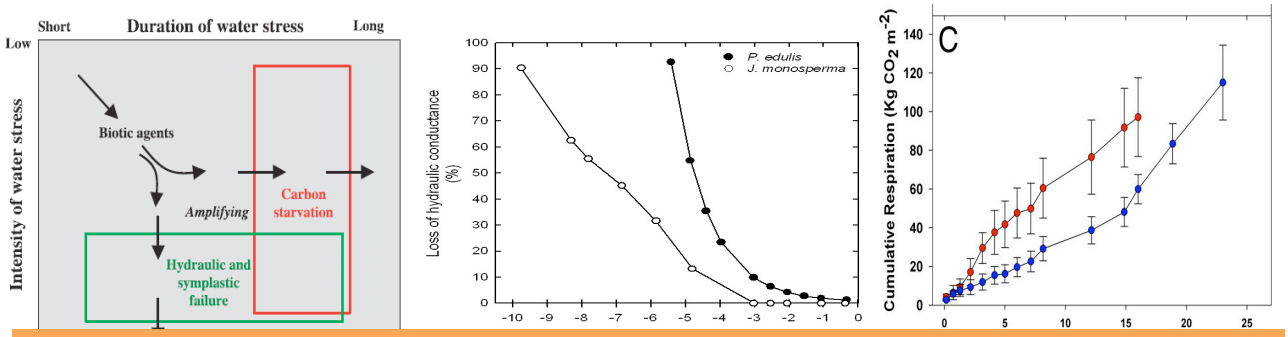


Figure 5. Mechanisms of tree mortality, leaf hydraulic conductance, and cumulative respiration in piñon pine and juniper.

hydraulic failure, carbon starvation, or some combination of both (Fig 5a). In addition, carbon starvation and drought stress can weaken trees and predispose them to successful attack by biotic agents (i.e., beetles in the case of piñon pine).

During prolonged drought, piñon pine should exhibit carbon starvation due to isohydric stomatal behavior (constant mid-day leaf H_20 potential [Ψ]). Piñon will close stomata to prevent excessively negative Ψ (Fig 5b). Closed stomata prevent uptake of CO_2 and photosynthesis, leading to a reduction in non-structural carbohydrates as respiration losses accrue during a drought event (Fig 5c). In contrast, juniper should be prone to hydraulic failure due to anisohydric stomatal behavior (Fig 5c). Plants with anisohydric stomatal behavior do not strictly regulate midday leaf Ψ allowing for continued

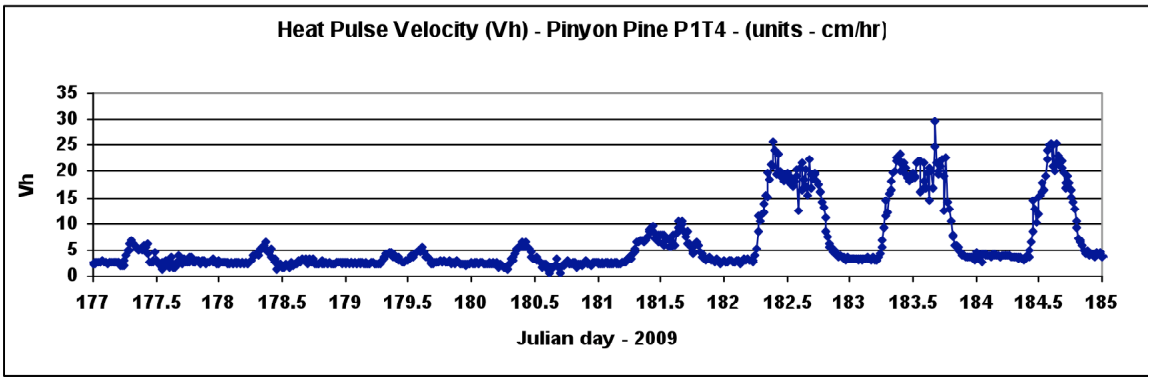


Figure 6. Data from 2009 piñon -Juniper measurements - Plot 1 showing heat pulse velocity in response to experimental rainfall events.

transpiration as soil water moisture declines during drought. To assess and model the hydraulic response to drought we measured tree transpiration (sap-flux – Fig 6), soil moisture (vol. % and Ψ), leaf gas exchange, stem and root hydraulic conductivity, and plant water stress (leaf Ψ). These variables are used to parameterize a hydraulic transport model that predicts tree transpiration and xylem hydraulic failure. We are testing the carbon starvation hypothesis by monitoring the temporal change in foliar and root non-structural carbohydrate levels, tree resin production, leaf gas exchange, and plant growth.

These measurements are designed to address key questions, such as, Do the hydraulic limitations of piñon pine (*Pinus edulis*) and juniper (*Juniperus monosperma*) significantly limit water use in this environment? Are transpiration patterns consistent with hydraulic failure or carbon starvation? The data will also be used to parameterize the Sperry (1998) model of water transport and calculate the critical transpiration rate (E_{crit}) which, if surpassed, would lead to catastrophic hydraulic failure. We will also compare measured E_s to modeled E_{crit} to predict risk of hydraulic failure.

So far we have found that the drought treatment negatively affected measured E_s in both species. Modeled hydraulic limits indicate that juniper maintained a large margin

Fig V. Piñon and Juniper water use envelopes

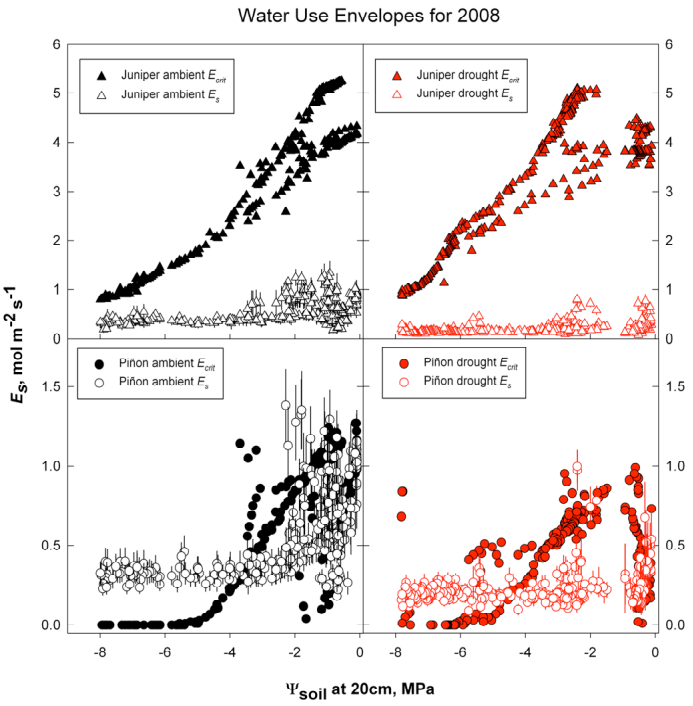


Figure 2. Low Piñon E_{crit}

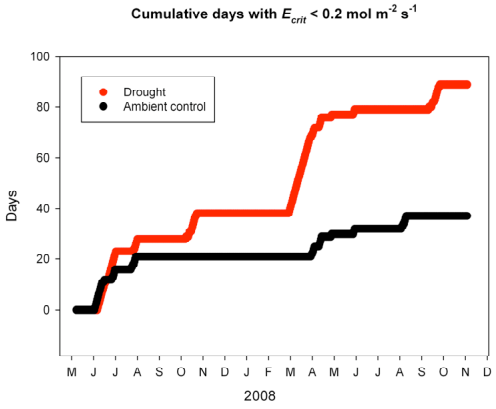


Figure 7. The relationship between soil water potential and transpiration rates for piñon and juniper on ambient and drought plots, and cumulative days with transpiration rates below e_{crit}.

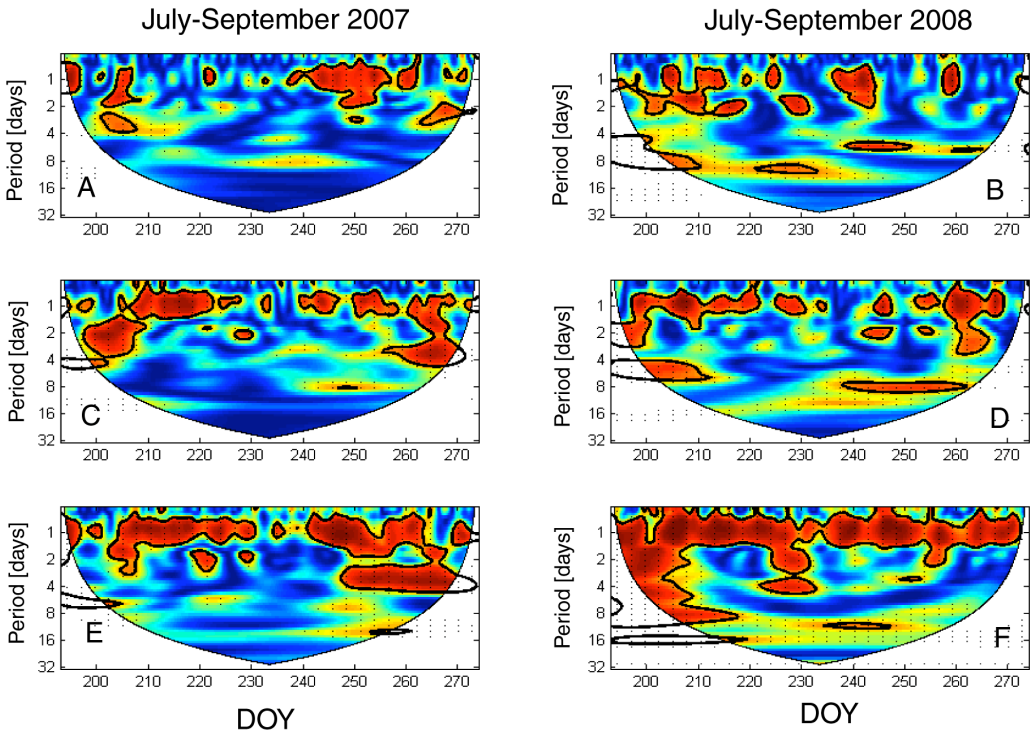
between E_s and E_{crit} (Fig 7), while piñon E_s exceeded E_{crit} when Ψ_s was below -3.5 MPa. In late July 2008 piñons on the drought plot were attacked by and succumbed to *Ips confusus* (bark beetles). Approximately 65% mortality was observed on the intensively instrumented drought plot within 2 weeks.

Juniper transpiration appears conservative relative to modeled hydraulic limits. Piñon appears to violate its hydraulic limits in both control and drought treatments, however we cannot attribute observed mortality solely to hydraulic failure because no mortality was observed in the control treatment. Consistent with a carbon starvation mechanism of mortality, piñon modeled E_{crit} reached extremely low values for twice as many days in the drought plot compared to the control plot (Fig 7).

Biogeochemistry

Large precipitation and soil respiration. (Rodrigo Vargas, Scott Collins, Michell Thomey, Jennifer Johnson, Renee Brown, Don Natvig, and Mike Friggens). Changes in the timing and magnitude of precipitation pulses will likely influence biogeochemical processes that regulate carbon dynamics in terrestrial ecosystems. Experimental data are necessary to measure changes in magnitude and synchronies of soil respiration to identify at which periods (e.g. day or weeks) biophysical mechanisms interact. We present results from a two-year study during a monsoon season (July-September) using a replicate

Figure 8. Wavelet coherence analysis between temperature independent soil respiration and PAR of rainfall manipulation experiments. The graphs represent two monsoon seasons (July-September 2007 and 2008) at (a,b) control, (c,d) small water addition, and (e,f) large water addition. The color codes for power values are from dark blue (low values) to dark red (high values). Black contour lines represent the 5% significance level and the edge black line indicates the cone of influence (COI). Values nearer the boundaries of the COI should be interpreted with caution. DOY means day of the year.



experimental design that included ambient precipitation plus one 20 mm rain event per month, ambient plus four 5 mm rain events per month, and ambient precipitation as controls in an arid grassland. We continuously measured soil respiration and apply wavelet coherence analysis to the time series derived from experimentally manipulated monsoon scenarios to determine at which periods different treatments influence the synchrony between soil respiration and PAR (as a surrogate for photosynthesis). We find that large precipitation events increase the magnitude of soil respiration in comparison with multiple short pulses and ambient scenarios. With higher magnitude and frequency of precipitation pulses we identify an increase in synchrony between soil respiration and biophysical mechanisms that act at a 1-day period. These results suggest that studies and models need to consider that timing and magnitude of precipitation pulses influence the

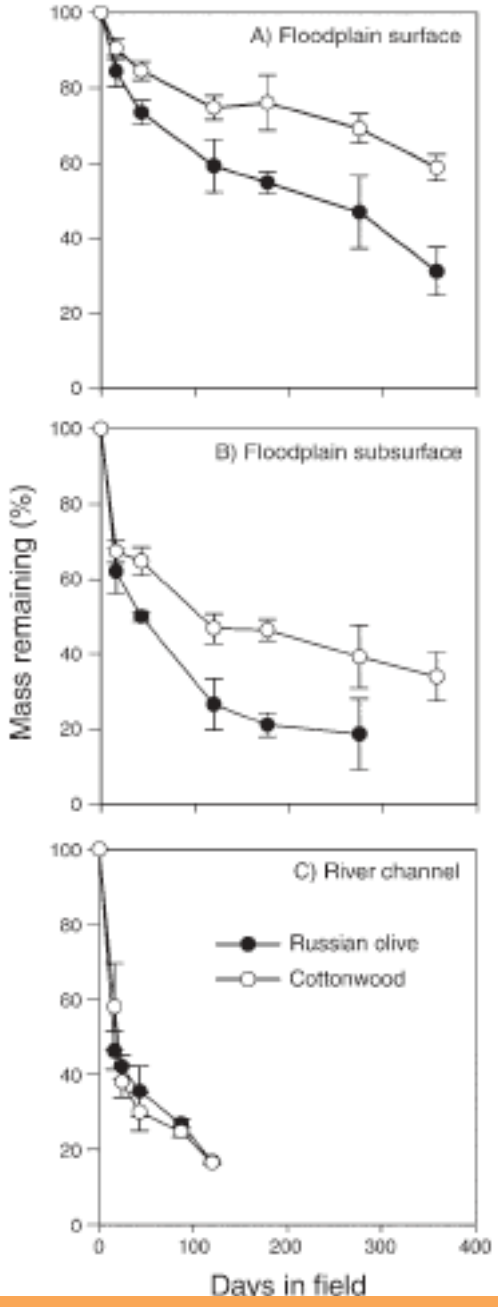


Figure 9. Decomposition of Russian olive and cottonwood leaf litter in (A) floodplain surface, (B) floodplain subsurface, and (C) river channel. Decomposition is expressed as the percentage of initial mass remaining. Values are means ± SE, based on 2–7 samples.

strength and periodicity of the mechanisms that regulate soil respiration in terrestrial ecosystems.

Riparian decomposition (Mary Harner, Chelsea Crenshaw, Manuela Abelho, Martina Stursova, Jenniver Follstad Shah, Bob Sinsabaugh). Dynamics of nutrient exchange between floodplains and rivers have been altered by changes in flow management and proliferation of nonnative plants. We tested the hypothesis that the nonnative, actinorhizal tree, Russian olive (*Elaeagnus angustifolia*), alters dynamics of leaf litter decomposition compared to native cottonwood (*Populus deltoides* ssp. *wislizeni*) along the Rio Grande, a river with a modified flow regime, in central New Mexico. Leaf litter was placed in the river channel and the surface and subsurface horizons of forest soil at seven riparian sites that differed in their hydrologic connection to the river. All sites had a cottonwood canopy with a Russian olive-dominated understory. Mass loss rates, nutrient content, fungal biomass, extracellular enzyme activities (EEA), and macroinvertebrate colonization were followed for three months in the river and one year in forests. Initial nitrogen (N) content of Russian olive litter (2.2%) was more than four times that of cottonwood (0.5%). Mass loss rates (k; in units of d^{-1}) were greatest in the river (Russian olive, k = 0.0249; cottonwood, k = 0.0226), intermediate in subsurface soil (Russian olive, k = 0.0072; cottonwood, k = 0.0031), and slowest on the soil surface (Russian olive, k = 0.0034; cottonwood, k = 0.0012) in a ratio of about 10:2:1 (Fig 9). Rates of mass loss in the river were indistinguishable between species and proportional to macroinvertebrate colonization. In the riparian forest, Russian olive decayed significantly faster than cottonwood in both soil horizons. Terrestrial decomposition rates were related positively to EEA, fungal biomass, and litter N, whereas differences among floodplain sites were related to hydrologic connectivity with the river. Because nutrient exchanges between

riparian forests and the river have been constrained by flow management, Russian olive litter represents a significant annual input of N to riparian forests, which now retain a large portion of slowly decomposing cottonwood litter with a high potential for N immobilization. As a result, retention and mineralization of litter N within these forests is controlled by hydrologic connectivity to the river, which affects litter export and in situ decomposition.

Photoaccelleration of decomposition in the riparian zone (Marcy Gallo, Andrea Porras-Alfaro, Kylea Odenbach, Bob Sinsabaugh). In arid ecosystems, abiotic processes facilitate the physical and chemical degradation of plant litter to the extent that decomposition models that use climatic and litter composition variables as surrogates for microbial activity are not predictive. The purpose of this study was to estimate the potential contribution of photodegradation to the decomposition of plant litters that varies in architecture and chemical composition. Litter of *Pinus edulis*, *Juniperus monosperma* and *Populus deltoides* was exposed to ambient and attenuated sunlight, with and without supplemental water additions, at a riparian forest site along the Middle Rio Grande (New Mexico). Mass loss, elemental composition, and microbial extracellular enzyme activities (EEA) were measured over 639 days. The composition of the fungal communities

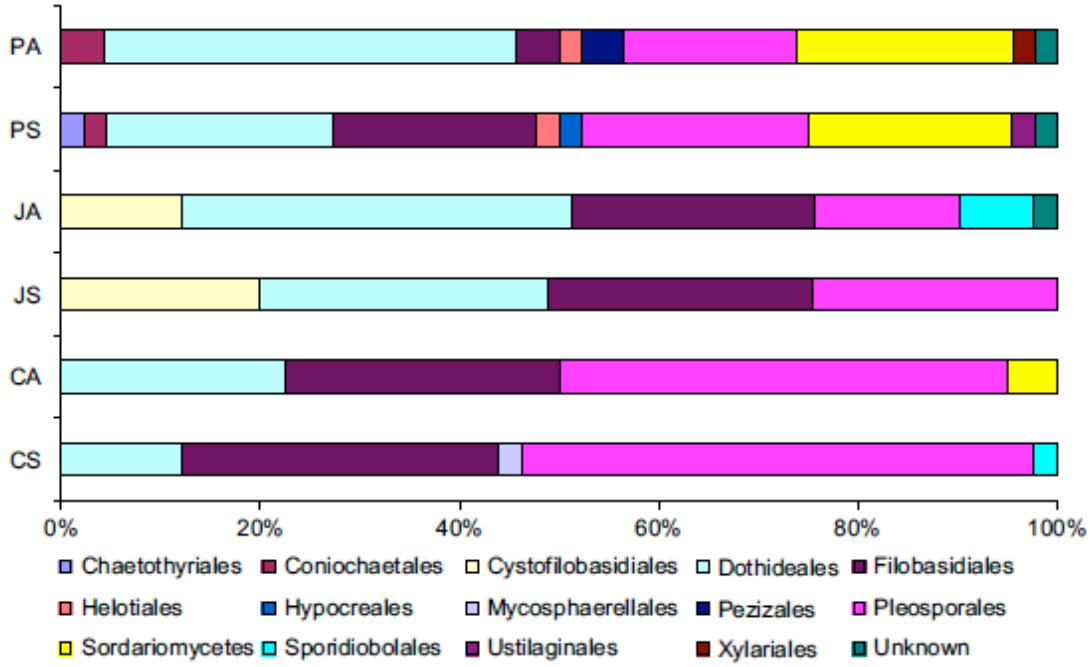
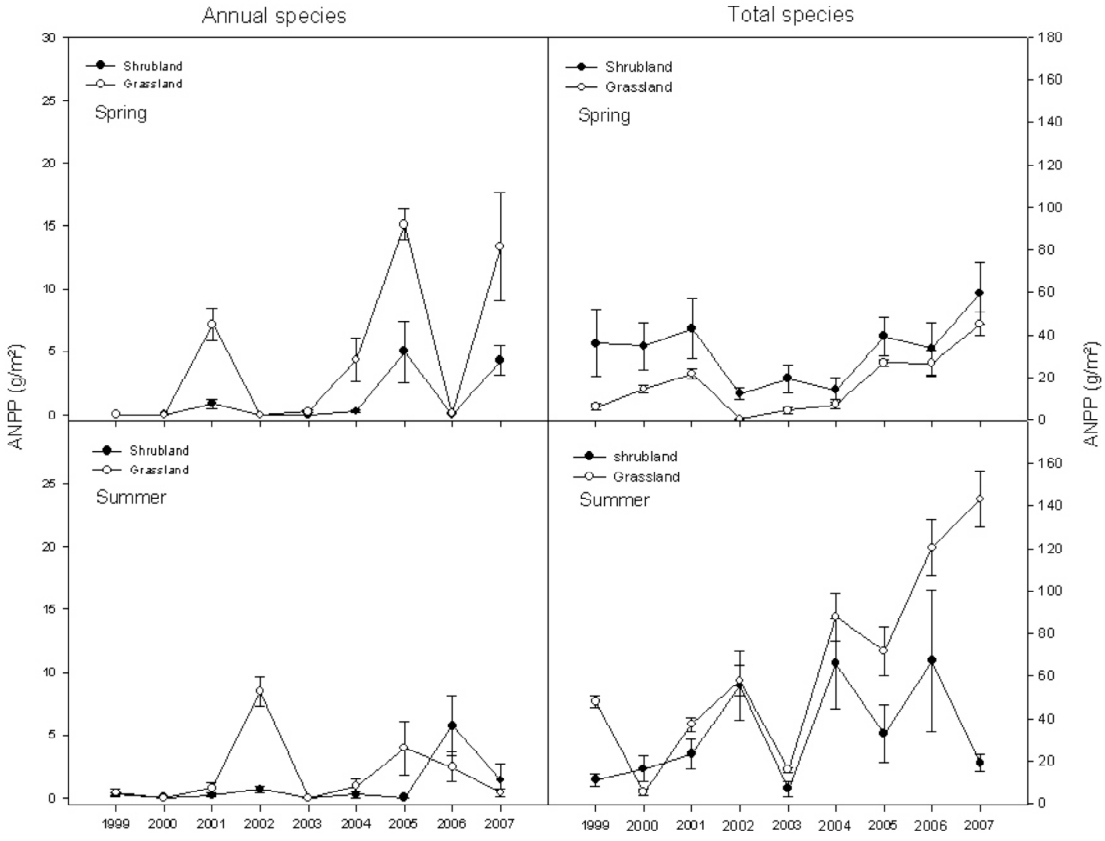


Figure 10. Proportional distribution of ITS fungal sequences by order based on GenBank blast results. P = pinon, C = cottonwood, J = juniper. S = shade treatment (20% ambient light), A = ambient light. Ascomycete orders are Chaetothyriales, Dothideales, Hypocreales, Pleosporales, Coniochaetales, Mycosphaerellales, Sordariomycetes incertae sedi, Xylariales, Helotiales, Pezizales. Basidomycete orders are Ustilaginales, Filobasidiales, Cystofilobasidiales, Sporidiobolales.

associated with the decomposing litters was compared by analyses of fungal ITS nrDNA sequences. Litter exposed to ambient sunlight had greater mass loss rates than shaded litter, independent of the water treatment: *Populus* increased by 100%, *Pinus* by 86% and

Juniperus by 46%. The increases were proportional to exposed litter surface area per g dry mass. EEA potentials, particularly oxidative activities, were low in comparison to those measured in mesic ecosystems. For *Populus* litter, the principal driver of photoacceleration appeared to be photodegradation of cellulose; for *Pinus*, it was photodegradation of polyphenols; for *Juniperus* accelerated mass loss was associated with photodegradation of both polysaccharides and polyphenols. Fungal community composition varied by litter type, but the dominant colonizers were yeasts and dark-septate hyphal taxa (Fig 10); a finding consistent with the low enzymatic oxidation potential. This study shows that photochemical oxidation can supplement enzymatic oxidation and increase decomposition rates. As a result, organic matter decomposition in arid ecosystems is not restricted to periods of high moisture availability as is plant production. This decoupling may partly account for the low soil organic matter content of these ecosystems.

Figure 11. Comparison of yearly variation of total ANPP (g m^{-2}), and ANPP of winter and summer annuals during spring and summer in *Bouteloua*-dominated grassland and *Larrea*-dominated shrubland.



Producer dynamics

<u>*Net primary production of desert annuals*</u> (Yang Xia, Doug Moore, Scott Collins, Este Muldavin). Precipitation variability and shrub encroachment in response to global environmental change are likely to affect both richness and aboveground net primary production (ANPP) of annual plants in arid and semi-arid ecosystems in the northern

Chihuahuan Desert, especially given the grazing history and desertification potential of this aridland region. Using a nine-year dataset (1999 to 2007), we examined the spatial and temporal variation in annual plant communities in grass- and shrub-dominated vegetation, and evaluated the relationships between species richness and ANPP with seasonal and annual precipitation and soil moisture. We found that species richness and ANPP varied among seasons and between years in both grass- and shrub-dominated areas (Fig 11). *Cryptantha crassisepala*, *Plantago patagonica*, and *Phacelia integrifolia* were the most common species found in both communities in both seasons, and *Chamaesyce serrula*, *C. serpyllifolia*, and *Kallstroemia parviflora* were more common in summer only. We found that species richness in summer was significantly correlated with summer precipitation and summer soil moisture in both communities, but summer ANPP was significantly correlated with summer precipitation and soil moisture only in shrubland. However, richness and ANPP of winter annuals were significantly correlated with winter precipitation and winter soil moisture in shrubland and grassland. Our results demonstrate that temporal variation in rainfall can be as important as annual total amounts for plant performance, and that response to temporal dynamics varies among species but not between grass- and shrub-dominated communities. We conclude that desert annuals provide a highly dynamic system for understanding the processes that influence plant species composition and abundance, and that desert annual systems will likely be highly impacted by shrub encroachment along with increases in precipitation variability as a consequence of anthropogenic climate change.

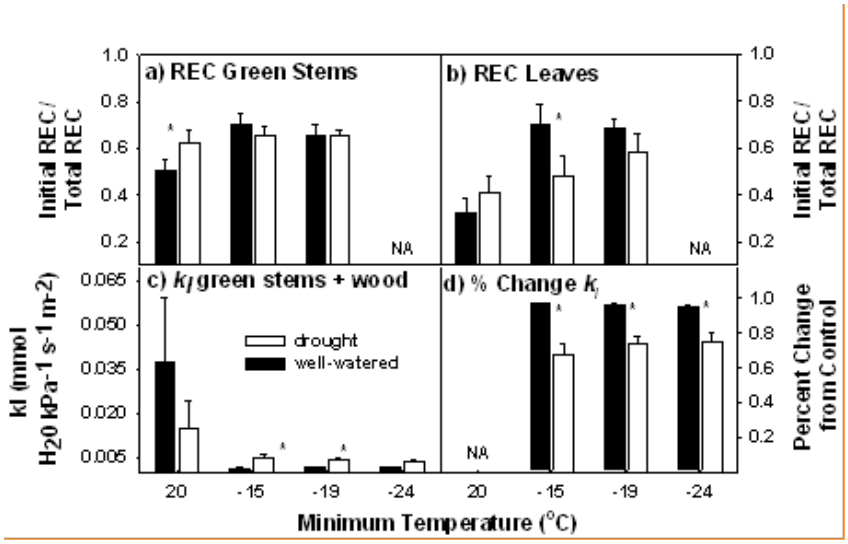


Figure 12. Physiological characteristics of leaves and xylem following four minimum temperature treatments, relative electrical conductivity in (a) green stems and (b) leaves, c) leaf specific hydraulic conductance of green stems+wood, and d) percent change leaf specific hydraulic conductance from control. Error bars represent standard error.

Mechanisms affecting shrub encroachment (Juliana Medeiros, Will Pockman). Freezing may limit the high latitude expansion of warm desert shrub populations and because drought and freezing often occur together in deserts, it is important to determine their interactive effects on plant performance and survival. To understand these effects on the leaves and xylem of *Larrea tridentata,* we measured survival, leaf loss and re-sprouting, plant water potential, gas exchange, relative electrolyte conductivity, freezing point depression, and leaf specific xylem hydraulic conductance following freeze/thaw events in well-watered and droughted

greenhouse-grown saplings following freezing to -8°C, -15°C, -19°C and -24°C. Following mild (-8°C) or extreme (-24°C) freezes drought and well-watered plants showed similar survival, but there was a significant positive effect of drought on freezing tolerance at intermediate freezing temperatures. Reductions in performance due to freezing were generally smaller among drought plants than among well-watered plants, and significantly more drought plants survived freezing to -15°C and -19°C. Drought plants had higher rates of leaf retention and re-sprouting than well-watered plants, which are close to the long-term minimum of -20°C measured at Five Points (Moore, 1989-2000). Following freezing to -15°C drought plants also exhibited higher rates of gas exchange and increased freezing point depression in leaves and green stems. The drought treatment also reduced the rate of cell death in green stems (Fig 12a); measured as relative electrical conductivity or REC) and leaves (Fig 12b). Drought plants also had higher leaf specific xylem hydraulic conductance (k_l) following freezing compared to well-watered plants (Fig 12c). Finally, in drought plants the percent loss of function in leaves (Fig 12b) was well coordinated with percent loss of function in xylem (Fig 12d), while in well-watered plants xylem was more vulnerable than leaves. Reduced cell death in concert with higher leaf specific hydraulic conductance following freezing in drought plants suggests a role for living cells in preventing or repairing embolism.

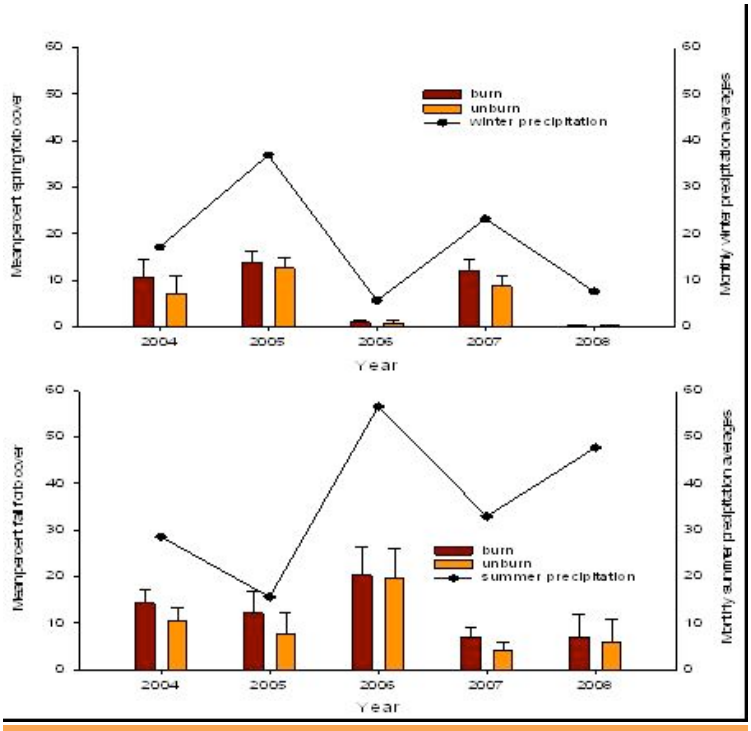


Figure 13. Forb productivity, total mean percent cover and monthly precipitation values for years following the 2003 prescribed fire.

Consumer Dynamics

Rodent disturbance and fire effects on plant community dynamics (Terri Koontz). Soil disturbance resulting from both biotic and abiotic factors can affect the composition of the plant community above and below ground. Small biotic scale disturbances, like ones from rodent digs, can create 'hot spots' containing unique combinations of species in the aboveground annual plant community. In the Chihuahuan desert grassland at the Sevilleta, one of the dominant rodents, the banner-tail kangaroo rat, creates living habitats of open gravely soil patches on the landscape. At a small scale these gravelly patches trap seeds where a seed can germinate, flower, fruit, and establish in a community. Fire, limiting resources, and abiotic disturbances can also affect plant populations and alter community structure. In this Chihuahuan grassland, fire increased the number of forb species and

forb production. However, certain extreme precipitation events, dry winters and wet summers, dampened the effects (Fig 13).

Implications of woody plant encroachment for mammalian predators (Virginia Seamster) Woody plant encroachment, or the spread of woody plants into a grassland area, is a widespread phenomenon and has the potential to impact the ecology of a large number of mammalian species. However, little is known about the magnitude or exact nature of this impact, especially for mammalian predators. The primary goal of this project is to assess the consequences of woody plant encroachment for the feeding ecology of a top, omnivorous predator. The specific question being addressed is: What is the base of the food chain for coyotes living in grassland vs. shrubland habitats in an area where woody plant encroachment has been occurring over the past century? The hypothesis is that woody plant encroachment will lead to a shift in coyote feeding ecology. In particular, coyotes in shrubland areas will obtain a high percentage of their food resources directly or indirectly from shrubs and there will be a positive relationship between the percent of the coyote diet coming from shrubs and percent woody plant cover. To test this hypothesis, data was collected in June to August 2008, April 2009 and July 2009 at the Sevilleta National Wildlife Refuge (NWR) and Long Term Ecological Research (LTER) site in New Mexico. A fourth field season is planned for October 2009. Data collection in 2008 consisted of the following: scat collection along 20 one mile long, road based transects and survey of vegetation within 40 circular plots (diameter=30m). Half of all transects and plots were located in grassland habitat, the other half in shrubland. In 2009, 22 scat transects were surveyed and data was collected for 22 vegetation plots (one per scat transect). In both years, scat transects were driven at <10 mph. Each scat sample encountered was measured (maximum diameter, length of longest piece, Fig 14) and then collected for future genetic and stable carbon isotope analysis. For each vegetation plot, total percent woody vegetation cover was assessed along 4x15m line intercept transects and vegetation samples were collected for future stable carbon isotope analysis.

Figure 14. Scat sample measurements.

Over 760 carnivore scat samples have been collected. Roughly 70% of the samples that have been run through a mitochondrial DNA species identification test (n=609) were from coyotes. Microsatellite data from approximately 40% of the collected samples shows that there is a minimum of 46 different coyotes at the study site.

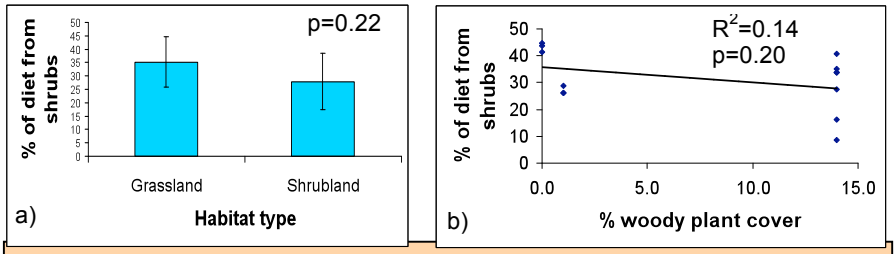


Figure 15. Carbon isotope results for a) grassland vs. shrubland areas and b) areas with increasing percent woody plant cover.

Preliminary stable carbon isotope data indicates that, contrary to expectations, grass is an important food source in both habitat types, percent shrub in the coyote diet is slightly higher for coyotes in grassland areas (Fig 15a), and there is a very weak (R^2=0.14), negative relationship between percent coyote diet coming from shrubs and percent woody plant cover (Fig 15b).

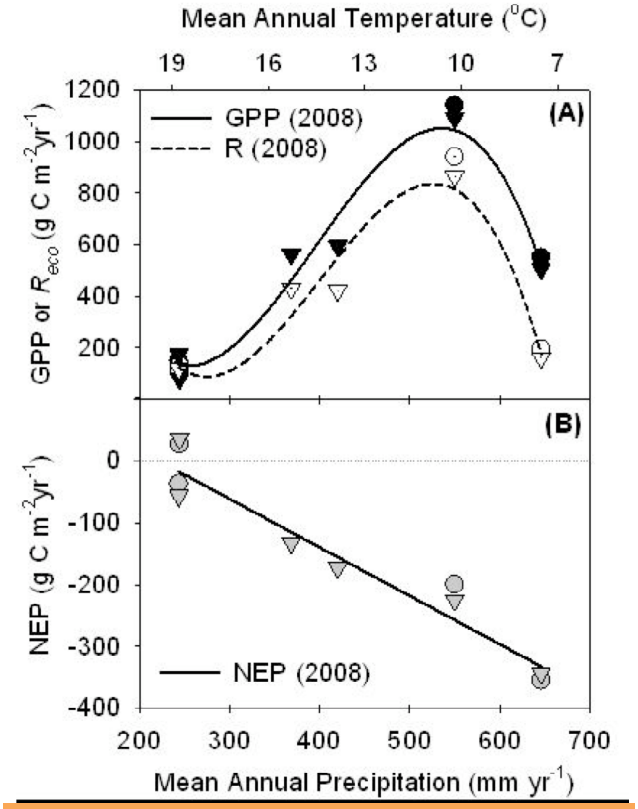


Figure 16. Annual carbon fluxes across the New Mexico elevational gradient in 2007 (circles) and 2008 (triangles): (A) annual GPP (solid symbols) and Reco (hollow symbols), and B) annual NEP (sign convention- negative indicates carbon sink). Mean annual precipitation and mean annual temperature are closely correlated across the gradient (R^2=97%), allowing for representation of both on the x-axis.

Ecosystem respiration (Marcy Litvak, Andy Fox). To determine how carbon storage varies across the major ecosystems in the southwest, we have established a network of eddy covariance flux towers in the following upland environments: desert grassland, desert shrubland, juniper savanna, piñon juniper woodland, ponderosa pine, and mixed conifer woodland. These sites occur along an elevation gradient that creates an increase in both annual precipitation and soil moisture, and a decrease in mean annual temperature. Towers at each site measure neat ecosystem exchange of carbon, water and energy. Results from 2008 show that gross primary production exceeds respiration in the forested habitats, but that grassland and shrubland habitats are either carbon neutral or small carbon sources to the atmosphere (Fig 16). As a consequence there is a strong correlation between mean annual precipitation and total C stored across these ecosystems. The next step is to estimate the land area associated with each habitat type to assess how these ecosystems combine to affect carbon dynamics in southwestern North America.

Social-ecological research

Socioecological Gradients and Land Fragmentation: A Cross-site Comparative Analysis. (Milan Shrestha, Sainan Zhang, Abigail York, Christopher Boone, Jack Wright, John Harrington, Mike Antolin, Barbara Nolen, Tom Prebyl, Mike Agar, Amaris Swann). This cross-site study organized a workshop on April 20 and 21, 2009 and developed a common methodology and action plans. We have a follow-up workshop scheduled for ASM 2009 (see abstract below). For all the LTER sites involved in this study, we used

the National Land Cover Dataset (NLCD) 1992 and 2001, compiled from Landsat TM satellite images. NLCD land-cover classes were reclassified into seven classes common for the southwestern United States. Using various fragmentation metrics, we quantified the fragmentation patterns for both the class-level and the landscape-level. While the detailed analysis is still in progress--mainly the analysis of the causes of land fragmentation for each site, some of the preliminary results of fragmentation analysis for the Sevilleta LTER site are appended below. Please note that the results are based on the transect shown on .

Increasing land fragmentation, mostly caused by urban sprawl and "leap-frog' developments, is a major concern in many rapidly growing metropolitan cities of the US. Land fragmentation affects biodiversity and ecosystem processes, as portions of the landscape become isolated without connecting corridors and this, in turn, can change ecological structure and function. This cross-site comparative study, a joint-collaboration of several LTER sites (i.e. Central Arizona-Phoenix, Sevilleta, Konza Prairie, Jornada Basin, and Shortgrass Steppe), takes a cross-site comparative approach to: (1) examine the land fragmentation patterns in some of the fastest growing southwestern cities of the US, and (2) understand the roles of urban population dynamics, water infrastructure, transportation networks, and annexation on land fragmentation.

Data used in this study are from the National Land Cover Dataset (NLCD) for the years 1992 and 2001, compiled from Landsat TM images. We reclassified the original land-use/cover classes of each research site into seven categories: developed (higher intensity), developed (lower intensity), agriculture/cultivated, forest, undeveloped/remnants, grass/shrubland, and water. We also quantified the fragmentation pattern through landscape metrics: Patch Density (PD), Interspersion and Juxtaposition Index (IJI), Contagion (CONTAG), Landscape Shape Index (LSI), Edge Density (ED), Shanon Density Index (SDI). We calculated these metrics for individual research sites and then

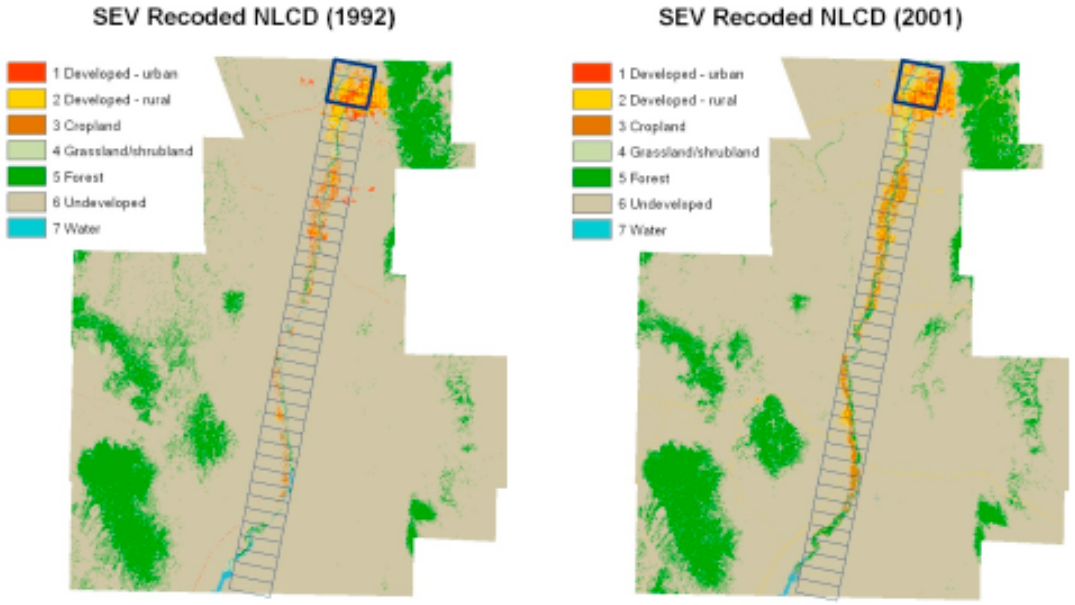
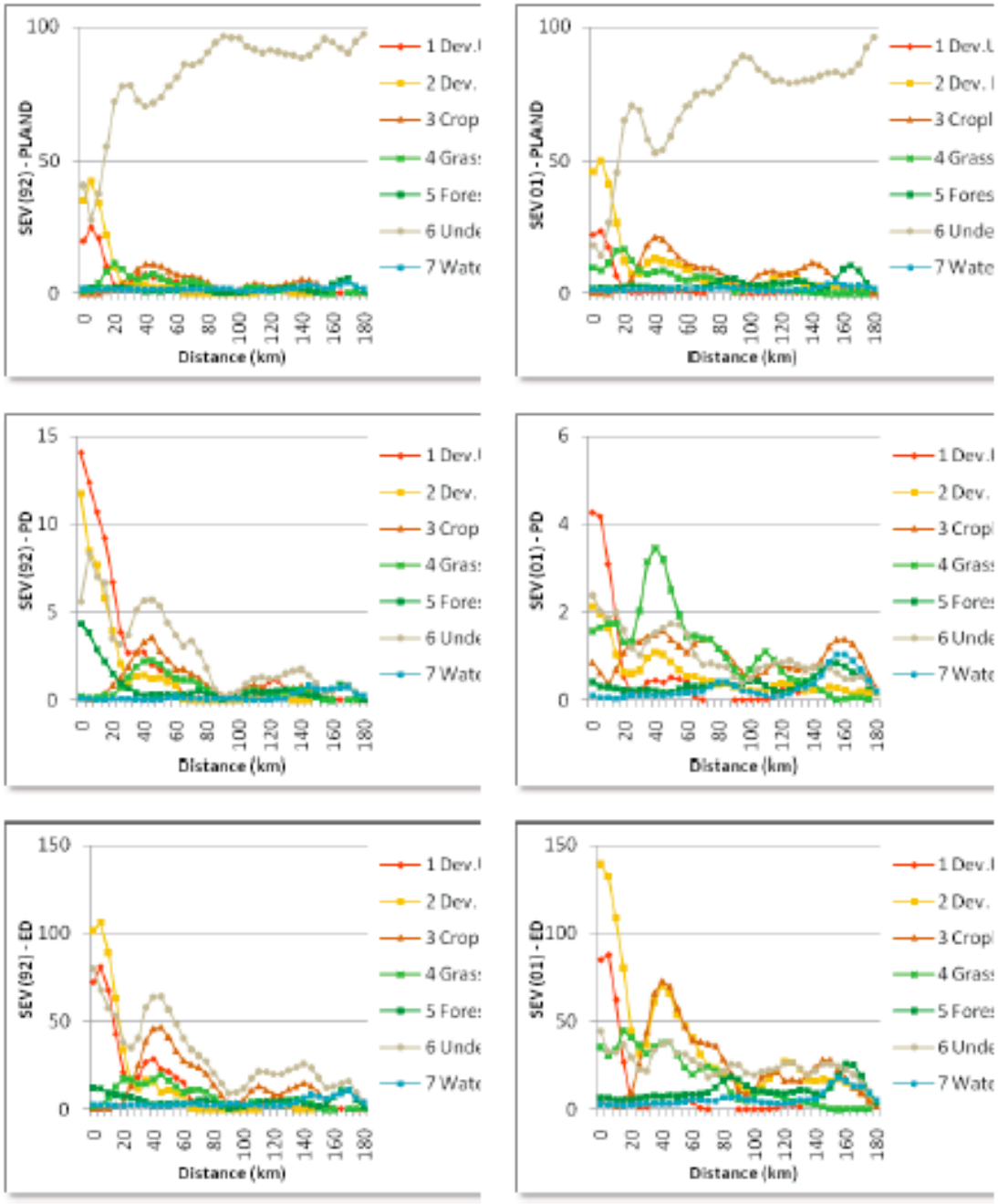


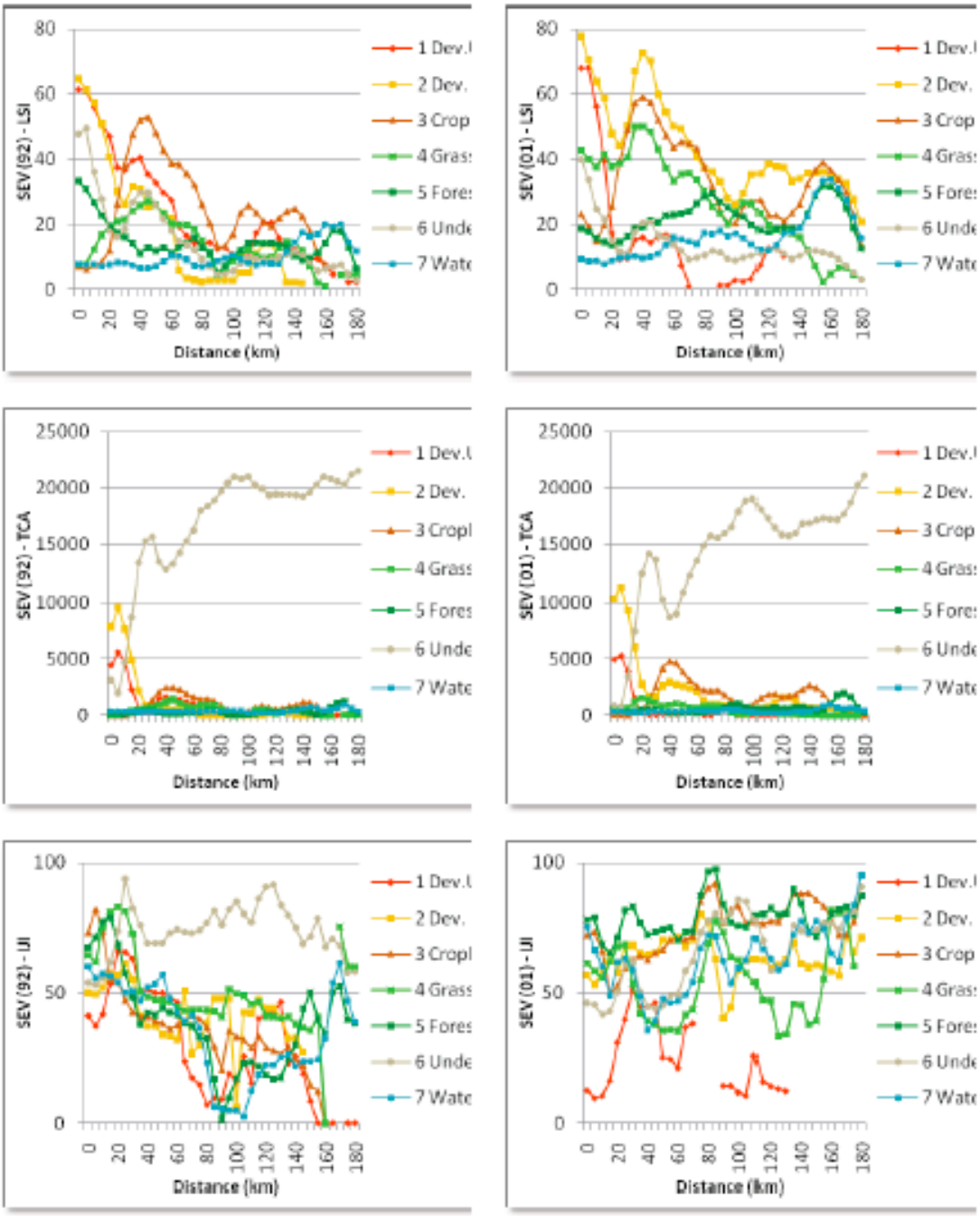
Figure 17. Study site showing the selected land cover classes in 1992 and 2001, and the transect (15km x 15km window moving 5km each time).

finally compared fragmentation patterns across these sites. The results of this study will help understand the patterns and the processes of land fragmentation in the Southwestern United States.

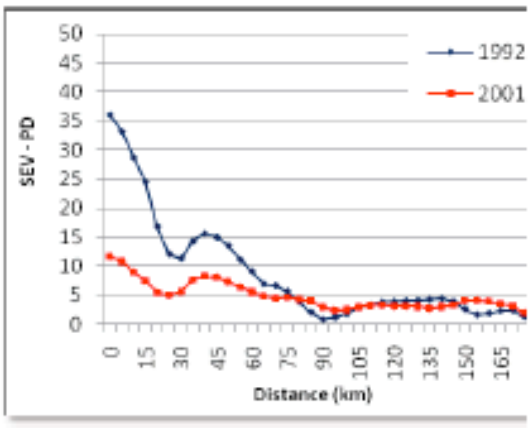
Preliminary results of the fragmentation analysis for the Sevilleta LTER site at the Class-level found that 1) developed rural areas and agricultural land have expanded along the transect, especially at 0-10km, 40km, 120km, and 2) the most fragmented areas for undeveloped land are located at 40km, 120km and 140km.

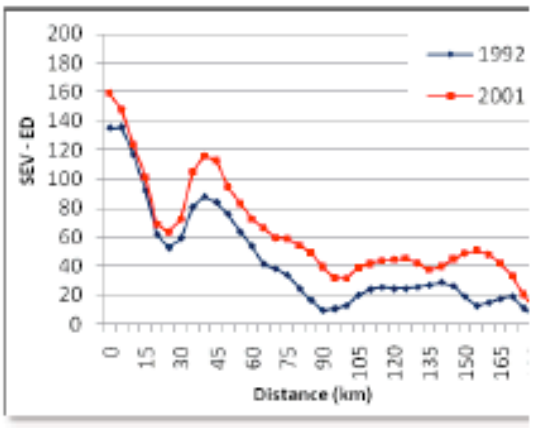


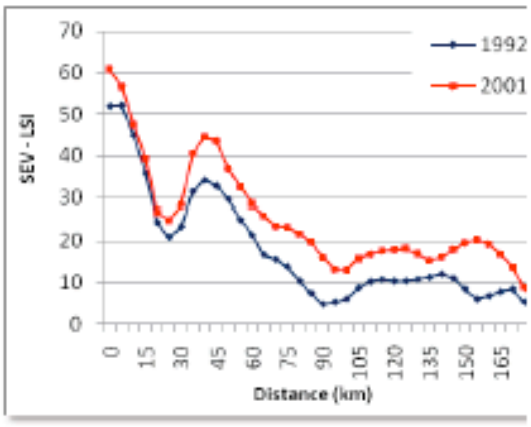
At the Landscape-level, except for the Patch Density Metric, all other metrics indicated a rapid fragmentation caused by the sprawl of developed land. The most fragmented area is in city center (0km-20km), but the area where fragmentation rose the fastest is distributed evenly through 40km to 160km.



Metrics at landscape level (1992 & 2001)


SEV - PD
1992
2001
Distance (km)


SEV - ED
1992
2001
Distance (km)


SEV - LSI
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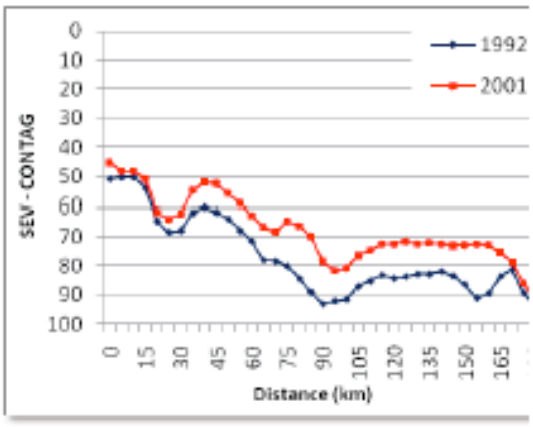
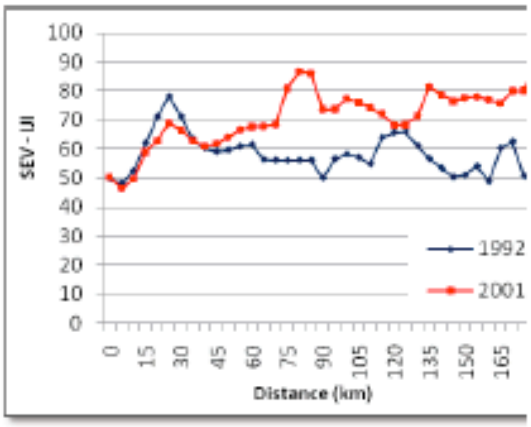

SEV - CONTAG
1992
2001
Distance (km)


SEV - IJI
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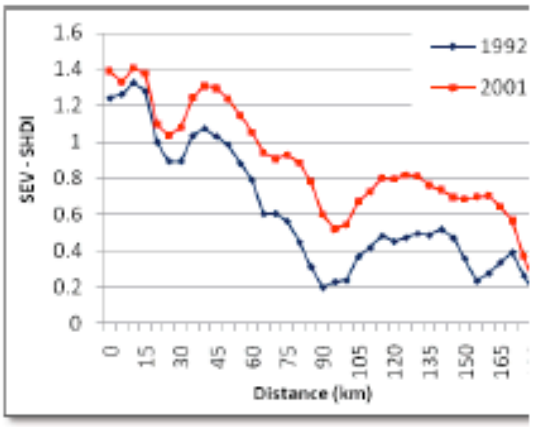
SEV - SHDI
1992
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Distance (km)