Research and management of soil, plant, animal, and human resources in the Middle Rio Grande Basin

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Abstract.-The Rocky Mountain Forest and Range Experiment Station initiated a research program in 1994 called. "Ecology, diversity, and sustainability of soil, plant, animal, and human resources of the Rio Grande Basin". This program is funded by an Ecosystem Management grant from Forest Service Research. Its mission focuses on the development and application of new knowledge to sustain ecological systems and human populations in the Middle Rio Grande Basin. Research studies emphasize upland ecology and management, linkages between watersheds and riparian zones, sensitive fish and wildlife populations and species of concern, and past and present cultural resources.

INTRODUCTION

The Rocky Mountain Forest and Range Experiment Station (RMS) of the USDA Forest Service initiated a research program in 1994 on "Ecology, Diversity, and Sustainability of Soil, Plant, Animal, and Human resources of the Rio Grande Basin" (Finch and Tainter 1995a). Research focuses on the middle Basin, defined as the segment of the Rio Grande between Cochiti and Elephant Butte Reservoir, New Mexico (Finch and Tainter 1995b). The mission of the program is to develop, synthesize, and apply new knowledge on processes, interactions, and sociocultural uses of upland and riparian ecological systems for sustaining diverse, productive, and healthy plant, animal, and human populations and associated natural resources in the Middle Rio Grande Basin.

Research studies have been implemented to address four problem areas of this temporary Research Work Unit (RM-RWU-4652). Problem analyses for each of the four focus areas were completed and published as Chapters 1-9 of the General Technical Report, *Ecology, Diversity, and Sustainability of the Middle Rio Grande Basin* (Finch and Tainter 1995a). The four problem areas are:

1. Short-term and long-term responses of upland soils, water, nutrients, belowground systems, and vegetation to historic and current perturbations caused by factors such as climate, grazing, and fire, including interpretation of how such responses influence dynamics, stability, and productivity of upland ecosystems (Loftin et al. 1995, Gottfried et al. 1995, Klopatek 1995);
2. Processes within fluvial ecosystems that form major linkages between upland catchments (watersheds), the Rio Grande, and its floodplain bosques (Fox et al. 1995);
3. Responses of plant, fish and wildlife species to barriers in dispersal, migration, and reproduction along the Rio Grande and selected tributaries, including identification of species of concern and development of methods for recovering populations and habitats (Finch et al. 1995, Rinne and Platania 1995); and
4. Improving understanding of the environmental history of the Rio Grande Basin (Scurlock 1995a, 1995b), the historic and contemporary

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human role in Basin ecosystems (Wozniak 1995), the nature and extent of anthropogenic disturbances to the Basin, and the sustainability of cultural diversity in the Basin (Finch and Tainter 1995b).

Rocky Mountain Station (RMS) scientists from Albuquerque, New Mexico, Flagstaff, Arizona, and Fort Collins, Colorado are participating in the program, representing disciplines such as anthropology, wildlife biology, fisheries biology, soil science, plant ecology, range science, forestry, and microbiology. Cooperators external to the Rocky Mountain Station include researchers from the following institutions:

- Sevilleta Long Term Ecological Research Site (LTER) and Department of Biology, University of New Mexico (UNM);
- Laboratory of Tree Ring Research, University of Arizona;
- National Biological Survey,
- Rio Grande Bird Research, Inc.,
- Southwest Region, U.S. Forest Service;
- Wingswept Research, Inc.;
- Desert Laboratory, U.S. Geological Survey;
- UNM Natural Heritage Program, and
- Fish and Wildlife Cooperative Unit, Oklahoma State University.

Additionally, partnerships have been developed with the following organizations who have provided study site access, housing, matching funds, equipment, vehicles, and expertise:

- Cibola, Santa Fe, and Carson National Forests,
- U.S. Fish and Wildlife Service, Region 2,
- Bureau of Land Management,
- Albuquerque Corps of Engineers,
- City of Albuquerque,
- Bosque del Apache Wildlife Refuge,
- Open Space Commission, Albuquerque,
- Rio Grande Nature Center,
- New Mexico Department of Game and Fish,
- New Mexico Partners in Flight,
- Bandelier National Monument, and
- Reio Grande Basin Consortium.

Recent accomplishments include participation in the Riparian Symposium that resulted in this proceedings. In particular, program participants gave papers, posters, and panels during a full day of the symposium devoted to "Rio Grande Basin Ecology and Management". Twelve papers prepared by RMS scientists and external cooperators of RM-RWU-4652 were published in the symposium proceedings. Accomplishments in Fiscal Year (FY) 1995 include completion of the GTR on the Middle Rio Grande Basin; about 40 presentations (e.g., invited talks, slide shows, posters, and field demonstrations) by team members on program research; team member participation in annual meetings and symposia of professional societies and groups such as The Wildlife Society, the Ecological Society of America, the North American Benthological Society, the Cooper Ornithological Society, International Rangeland Congress, and the Interior West Global Change Workshop, to name a few. RWU-4652 Team Leader Deborah Finch was elected Chair of the Rio Grande Basin Consortium, a coalition of agencies and organizations interested in developing methods and projects for sustaining Rio Grande Basin environments (for more information, see Potter and Finch, this issue). Consortium activities have been integrated with research program objectives where possible.

The next section describes research studies initiated under and funded by this umbrella program.

PROBLEM 1: UPLAND ECOSYSTEMS

Ecology and restoration of upland basin rangelands

Successful restoration of grassland ecosystems that have been damaged by disturbances such as historic overgrazing, drought, road-building, or recreation often involve intervention with treatments that will interrupt the desertification process and re-establish natural ecological processes. Current studies are assessing responses of soil nutrients, water, belowground ecosystems, and herbaceous plants to restoration treatments, and developing and evaluating various methodologies that can be used to successfully repair damaged grasslands invaded by woody and weedy species.

Experimental studies by Principal Investigators (PI) Dale Brockway and Samuel Loftin, RMS, Albuquerque, New Mexico, and Carole Klopatek, RMS, Tempe, Arizona were initiated in FYs 1994 and 1995 to assess the restoration benefits and success of prescribed fire and/or thinning of woody plants in blue grama grasslands, transition zones, and pinyon-juniper woodlands that are either protected from grazing (Sevilleta LTER) or are heavily grazed and showing signs of stress (e.g, high erosion, loss of ground cover, gullying). Study plans have been completed and approved for three studies, and experimental plots have been installed. Pi-e-treatment data were gathered in FY 1995 for the prescribed fire and thin/slash studies, and a 2nd year's data were collected for a slash mulch study on the Santa Fe National Forest. Loftin et al. (1995) and Klopatek (1995) describe research needs in shrub-invaded and belowground ecosystems in more depth in Chapters 6 and 9 of the Rio Grande GTR.

A final report was completed and approved for Cooperative Agreement 28-C4-799 (PI Carl White, UNM) evaluating nutrient cycling, soil moisture dynamics, and plant community ecology associated with historic cobblemulch gardens built by American Indians. This study included an experiment to determine the value of cobblemulch in restoring rangeland conditions. Manuscripts are under preparation.

Rangeland/woodland ecotonal responses to climate change

Studies of effects of climate change on pinyon-juniper woodlands and associated ecotones are underway through two cooperative agreements, No. 28-C4-800 with University of Arizona's (UA) Laboratory of Tree Ring Analysis (PIs Thomas Swetnam, UA, Julio Betancourt, U.S. Geological Survey, Desert Laboratory, and Gerald Gottfried, RMS, Flagstaff, Arizona) and No. 28-C4-860 with UNM (PI Bruce Milne, UNM Department of Biology and Sevilleta LTER). In its second year, the UA study is assessing masting, demography, and condition of pinyon by analyzing tree rings and then relating age structure, mortality, and recruitment rates to historical climate change (also, see Betancourt et al. 1993). The UNM study is evaluating boundary shifts in pinyon-juniper woodlands at landscape and regional scales in response to historic climate change. Both studies will provide information on factors contributing to woodland invasion and recession at the local and landscape levels. Such information is essential for interpreting condition and health of pinyon-juniper woodlands and corresponding ecotones. These studies will supply a scientific basis for prioritizing approaches to manage or restore rangelands and pinyon-juniper woodlands. Gottfried et al. (1995) describe the value of this kind of research in depth.

Research natural areas in the Middle Rio Grande Basin

The following studies on Research Natural Areas (RNA) were funded by matching RNA and RWU 4652 dollars under Cooperative Agreement 28-C4-807. Mesita de los Ladrones RNA, a remote, 700 ha mesa-top on the Santa Fe National Forest, supports a pinyon-juniper woodland that has been excluded from grazing, woodcutting and fire for at least 100 years. PIs Esteban Muldavin and Juanita Ladyman, UNM Natural Heritage Program, predicted a fine grain pattern of herbaceous plant species in a protected pinyon-juniper RNA. To evaluate spatial pattern and association of herbaceous species, 750 contiguous 25 x 50 cm quadrats were established along two replicate transects through the RNA. Sliding window analysis revealed relatively sharp boundaries between C4 and C3 grass-dominated communities related to subtle soil and topographic changes. Within the C4 communities, fine grain patch size ranged from 2.5 to 12 M among the seven species present with the exception of blue grama, the common dominant of disturbed woodlands, which exhibited no fine scale patch structure between 0.5 and 380 m. In C3 dominated communities large patches between 50 and 100 m were predominant. Spearman's rank correlations indicated moderate to strong negative correlations among the major grass dominants of these ecosystems. Results were presented at the International Association of Vegetation Science Symposium, Rice University, June 5, 1995.

A second study under Cooperative Agreement 28-C4-807 is evaluating age structure and density of an old growth ponderosa pine forest in relation to changes in fire regime and climate fluctuations. Monument Canyon RNA in the Jemez Mountains,

Santa Fe National Forest, has been protected from logging, fire, and grazing since the turn of the century. Study results show that forest age structure is distinctively multi-modal with a remnant overstory of older trees (>300 years) that are dead or dying. The understory is dominated by very dense pole stands in excess of 5,954 stems/ha. A 300+ yr fire history chronology developed for the stand shows that changes in stand structure are correlated with changes in fire regime with consequent impacts on recruitment. Recruitment may reflect specific climatic pulses leading to high density, even-aged cohorts that lack thinning or removal by fire. High density in the understory is suggested to have negative impacts on nutrient cycling and moisture competition which are increasing the rate of overstory mortality, leading to a different kind of old growth forest that would have been expected under pre-settlement conditions. These results were reported by Esteban Muldavin, Thomas Swetnam, and Mary Stuever at the Ecological Society of America's annual meeting, Snowbird, Utah, August, 1995.

A literature review on the role of cryptogamic crusts in pinyon-juniper woodlands located in RNAs was completed under Cooperative Agreement 28-C4-807, also. A draft manuscript was submitted to RWU 4652 in February 1995 by Juanita Ladyman and Esteban Muldavin, peer reviews were solicited, and the manuscript is currently under revision.

Species of concern in upland woodlands

Summer 1995 was the first field season for a study examining population status, species composition, abundance, and maternity roost requirements of threatened, endangered, and sensitive bats captured in pinyon-juniper habitats of the Middle Rio Grande Basin. Ten sites distributed across five mountain ranges of the Cibola National Forest were netted four times throughout the summer. Nets were placed over permanent water sources where bats often feed or drink in the course of a night. Number of species and total numbers of bats captured were highly variable at any one site, ranging from 0-11 species/site and 0-134 bats/night.

Radiotransmitters were placed on reproductive females of three Category 2 candidate species (*Myotis volans*, *Myotis thysanodes*, and *Myotis evotis*) and efforts were made to relocate the females in their maternity roosts after release. Five of the radiotagged bats were relocated and found colony-roosting in trees, most of which were ponderosa pine snags or broken tops with long vertical cracks (most likely caused by lightning strikes). Colony size varied from 30 to 200 maternal bats per roost. Problem analyses on bats and other upland species were incorporated into two chapters, pinyon-juniper woodlands (Gottfried et al. 1995) and grassland/shrubland ecosystems (Loftin et al. 1995), of the 1995 Rio Grande GTR. Preliminary data on bats were presented in a poster at the Riparian Symposium in Albuquerque, Sept. 1995, and results are published (Alice Chung-MacCoubrey this issue).

PROBLEM 2: WATERSHED ANALYSIS AND STREAM QUALITY

A problem analysis on climatic influences, hydrological processes, and watershed management in the middle Rio Grande Basin was published as Chapter 4 of the Rio Grande GTR (Fox et al. 1995). Chapter authors are actively pursuing research under Problem 2 of the Rio Grande Program, with emphasis on water and stream quality, nutrient dynamics, and vegetative cover in the Rio Puerco Watershed. The Rio Puerco is a major tributary of the Rio Grande and one that scientists and managers concur has been heavily damaged by historic livestock grazing. The Rio Puerco is estimated to contribute 40% of the non-point source pollution found in the Rio Grande. A University New Mexico class project that reported strategies to address nonpoint source pollution in Bear Canyon Watershed was also financially supported by RM-RWU-4652 (Roth et al. 1994).

Lightning and precipitation study

Deborah Potter, a U.S. Forest Service physical scientist in the Southwest Region's Watershed and Air Staff Group, was detailed to RM-RWU-4652 in FY 1994 to complete a Ph.D. dissertation at UNM on spatial relationships among lightning, precipitation, and vegetative cover within the Rio Puerco watershed of the middle Rio Grande Basin. The

study site is a 110 km^2 area that includes Pole Canyon and Prop Canyon, Cibola National Forest. To test the hypothesis that areas receiving equivalent amounts of precipitation during the monsoon season have similar vegetation responses, remotely-sensed lightning data from Direction Finders Network, Boise Interagency Fire Center, and vegetative data from the Cibola National Forest Terrestrial Ecosystem Survey are being compiled and analyzed. Final products will include GIS thematic maps of the study area that display precipitation and vegetative cover, and also precipitation contour maps. This work is funded by Cooperative Agreement No. 28-C4-810 between RM-RWU-4652 and Department of Biology, UNM. Two progress reports have been completed and approved, and a first chapter of the dissertation is published in this proceedings (Potter and Gorman this issue).

Rio Seiiorito nutrient dynamics study

A study of the effects of livestock grazing on nutrient dynamics was initiated on the Rio Seiiorito, a small tributary of the Rio Puerco in northcentral New Mexico where the Bureau of Land Management has constructed three 600-m grazing exclosures separated by 200-m gaps. This study is funded by Cooperative Agreement No. 28-C4-833 between RM-RWU-4652 and UNM (PI Maurice Valett, UNM Department of Biology). As anticipated, no statistical differences were found in nutrient concentrations of ice-covered surface water and ground water between grazed and ungrazed plots during winter. Data suggest phosphorous limitation of primary production. During spring runoff NO3-N concentrations were elevated in surface water. Preliminary results indicate a stream with high organic carbon content, metabolically active sediments and microbially-mediated nutrient dynamics that vary with hydrologic conditions.

Future goals are to survey the hydrology of the study reaches and compare nutrient retention in gaps and exclosures using tracer experiments. Higher rates of biological activity in segments protected from livestock and ore efficient cycling of N and I' are hypothesized in these communities. Sewards and Valett (this issue) present preliminary results in this proceedings.

Roads and geomorphic controls in the Zuni Mountains

The objectives of this study are to determine the relationships between subsurface geomorphic features and the locations of riparian and wetland ecosystems along forest roads in the Zuni Mountains on the Cibola National Forest near Grants, New Mexico, and to evaluate the effects of road modification and construction activities planned for these forest roads. Investigators will be able to assess present conditions, make recommendations to the road engineers and then monitor changes that may take place following road construction and or other modifications. Ground Penetrating Radar (GPR) in conjunction with soil and vegetation surveys will be used to assess ecosystem conditions in selected study areas along Forest Roads 49 and 50 in the Zuni Mountains. Permanent transects and sampling points were established before road modifications began so that ecosystem changes in response to road activities could be monitored and documented. PIs include Daniel Neary and Roy Jemison, RMS, Flagstaff, Arizona; Dale Brockway, RMS, Albuquerque, New Mexico; and Phillip Guertin, Watershed Hydrology Department, University of Arizona.

PROBLEM 3: RIPARIAN SPECIES OF CONCERN

Stopover ecology of neotropical migratory birds

The Rio Grande is an important flyway for neotropical migratory birds, but its "bosque" has changed greatly over the past 100 years owing to exotic woody plant invasions, dams and diversion structures, urban expansion, water pollution, irrigation practices, agricultural conversion, and flood control. Finch et al. (1995) review research needs for Rio Grande bosque habitats, including habitat relationships of birds and arthropods. Our bird migration study assesses use and availability of stopover habitat for neotropical migratory landbirds during their north-south migration. Birds were captured in mist nets, measured, banded, and released in the spring and fall at the Bosque del Apache Wildlife Refuge and the Rio

Grande Nature Center, Albuquerque. Capture/recapture records provide an index to migration volume and timing, length of stopover, population status, and body condition and health, by species, sex, and age. To assess the value of different stopover habitats, point counts of migrating birds were conducted in native cottonwood-willow, exotic salt cedar, exotic Russian olive, and agricultural fields. Preliminary results are reported by Wang and Finch (this issue).

Arthropod populations and bird foraging behavior were also sampled along count routes. With Army Corps funds, vegetation types on the middle Rio Grande mapped in 1984 are being remapped to determine habitat change over a ten-year period (Mount et al. this issue). Research findings will be used to define methods, localities, and benefits for restoring migratory songbird habitats in the Rio Grande bosque. Bird and bosque studies are coordinated by PIs Deborah Finch, Project Leader, RMS, and Wang Yong, Visiting Scientist, RMS, and include two cooperative agreements, one on bird migration (28-C3-751, University of Southern Mississippi, Frank Moore and Wang Yong) and one on bird and arthropod interactions (28-C4-814, PIs Clifford Crawford and Mary J. Mund, UNM Department of Biology). Seven oral presentations and two posters were given on aspects of this integrated research, two papers *were* published including one by Wang and Finch in this proceedings, and four are in press.

Cowbirds and the Southwestern Willow Flycatcher

The Southwestern Willow Flycatcher (*Empidonax traillii exigua*) was federally listed as Endangered in March 1995. Declines in its population are associated with loss and conversion of its native shrub willow habitat, loss of backwater ponds due to flood control, invasion of exotic woody plants, and cowbird parasitism. Although the population status, parasitism rates, and general role of the brown-headed cowbird (*Molothrus ater*) in New Mexico are barely known, federal and state agencies have already advocated cowbird control measures as a step to recover willow flycatcher populations. To provide a scientific basis for flycatcher recovery in relation to cowbirds, a comprehensive literature review was conducted in FY 1994-95 assessing the relationships between cowbirds, hosts, and riparian habitat use in New Mexico, with emphasis on the flycatcher. This work is funded by Cooperative Agreement 28-C4-853 between RWU-4652 and Oklahoma State University. One oral presentation and one poster were given in FY 1995, and a paper is published in this proceedings (Schweitzer et al. this issue).

Fish species of concern

A problem analysis on fish species of concern in the Rio Grande Basin was completed and published in the Rio Grande GTR (Rinne and Platania 1995), and a chapter on the Rio Grande cutthroat trout was published in the Cutthroat Trout Conservation Assessment (Rinne 1995). John Rinne, RMS, Flagstaff, Arizona, and Robert Calamusso, New Mexico State University, are the leads for this research. Studies were initiated in FY 1994 to update current knowledge on the distribution of the Rio Grande cutthroat trout, a sensitive species formerly abundant in the headwaters of the Rio Grande in Colorado and northern New Mexico, and its co-occurrence with two native cyprinids, the Rio Grande sucker, a fish listed by the State of Colorado, and the Rio Grande chub (Calamusso and Rinne this issue).

The Rio Grande cutthroat trout was found to co-occur with the Rio Grande sucker on 1 creek on the Carson National Forest and 4 creeks on the Santa Fe National Forest. It co-occurred with the Rio Grande chub on 4 Carson National Forest creeks. All three species co-existed in Clear Creek, American Creek, and Rito de las Palomas on the Santa Fe National Forest. Seven new locations on the Carson National Forest were added to the distribution records of the Rio Grande cutthroat trout. Future objectives are to identify the role of physical and biological factors in fragmenting the distribution of these fish.

PROBLEM 4: HUMAN DIMENSIONS

Environmental history

A comprehensive environmental history and climatological review is under preparation by Dan Scurlock, Wingswept Research, Inc., under con-

tract RM-28-JV4-795. A preliminary history of the Middle Rio Grande Basin is presented in the Rio Grande GTR (Scurlock 1995a) and in a Global Change publication (Scurlock 1995b). Scurlock's study reveals major impacts on and changes to Middle Basin ecosystems over the past 450 years, since European entry into the region. Various land uses, such as grazing, intensive irrigation agriculture, logging, and construction of flood control features, combined with climatic fluctuations, have produced adverse changes in stream flow-morphology, ground water levels, topsoils, biotic communities, and individual plant and animal species. Indigenous human populations have been affected by these modifications also. Continued land-water use impacts from a rapidly increasing regional population suggest ongoing changes and major challenges for natural and human resource management organizations.

Human ecology and cultural resources

A specific review and problem analysis of the ecology and role of humans in the middle Rio Grande Basin was completed by Frank Wozniak, Forest Service Archaeological Consultant and published in the Rio Grande GTR (Wozniak 1995). According to this study, available technology and levels of technological knowledge have profoundly influenced human-generated impacts in both riparian and upland ecosystems. Understanding these impacts includes research on the influence of intensive irrigation agriculture introduced by the Spanish in the seventeenth century and the building of railroads by the Anglo-Americans in the nineteenth century. Research into the impacts of introduced domesticated plants and animals, especially cattle and sheep, over the past 450 years is also crucial to understanding the present-day ecosystems of the Basin.

As an adjunct to this research, the Rocky Mountain Station will publish a revised and updated version of a comprehensive document and literature review of irrigation in the Rio Grande Valley from prehistoric times to the present, conducted by Wozniak. This project will be undertaken during 1996.

Several papers on human dimensions research in the middle Rio Grande Basin were presented by RMS scientists and cooperators at the Riparian Symposium. Included were presentations on "human impacts on riparian ecosystems" (Wozniak this issue); "riverine settlement in the evolution of prehistoric land-use systems" (Tainter and Bagley Tainter this issue); "historic land use and grazing patterns" (Raish this issue) and "cobble mulch gardens" (Periman this issue). Raish and Periman also arranged a panel on the human role in shaping riparian ecosystems at the Riparian Symposium. The panel presentations, as well as the previously mentioned papers, are published in this proceedings. Joseph Tainter also presented a talk on Rio Grande Basin riverine settlement at The Wildlife Society's 2nd Annual Conference in Portland, OR, September 12-17, 1995.

A paper concerning resource conflict among the three primary ethnic groups resident in the Basin (American Indians, Hispanos, and Anglos) was presented by Raish at a conference on environmental dimensions of cultural conflict, organized by Tainter, RMS Project Leader, Cultural Heritage Research Work Unit, Albuquerque, and Brian Ferguson, Rutgers University. This research will be published in the issue resulting from the conference and will form a background to a future RMS study of the role of cultural differences in the perception of sustainability and sustainable resource use. Plans for development of this project are currently underway with anticipated completion of the research design and study plan in early 1996.

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