

Chapter 2

Environmental History

Dan Scurlock, Wingswept Research, Albuquerque, New Mexico

HISTORIC PERIODS

Spanish Colonial	A.D. 1540–821
Mexican	A.D. 1821–1846
Territorial	A.D. 1846–1912
Statehood	A.D. 1912–present

INTRODUCTION

Humans are a major component of the environment, and all human activities impact the environment, which includes other humans. Researchers have only recently focused on spatial and temporal impacts of historic human activities on the land and water of the Middle Rio Grande Basin. Interrelationships of these and the effects of periodic severe cold periods, early or late frosts, droughts, insect infestations, and other “natural disasters” such as epidemic diseases, earthquakes, fires, and floods have been minimally explored but not systematically studied. Furthermore, the equally complex history of plant and animal introductions and extinctions by humans, although generally understood, still need additional research of their temporal and spatial occurrence and impact on other biotic components. Finally, the role of world view exhibited by various groups as related to environmental impact, change, and future resource management needs must be considered.

Various groups in the Middle Rio Grande Basin ecosystems have greatly affected the processes and evolution of plant and animal communities during the historic period, A.D. 1540 to the present. The human-generated impacts and changes, through activities such as farming, hunting, ranching, mining, logging, stream impoundment, and recreation, have affected ecosystems’ structure, function, and eco-dynamics over the past 450 years. Some of these activities have reduced vegetative cover and, combined with periodic droughts and fires, have resulted in high rates of surface run-off due to precipitation and associated erosion. Silt from this process has, generally, increased through time and the resulting impacts

on riparian plant and animal communities have been severe in places such as the Middle Rio Grande Valley and Rio Puerco. Other impacts such as introducing exotic species of plants, animals, and toxins, diverting water for irrigation, and constructing dams have also brought dramatic changes to riparian ecosystems. This chapter summarizes human impacts and their interaction with the Middle Rio Grande Basin.

OVERVIEW OF ENVIRONMENTAL HISTORY

Climate

Weather records dating from the late 19th century to the present indicates that most of the region (excluding the mountains) is a continental plateau with arid to semi-arid climate. Salient characteristics include an average annual precipitation below 15 inches; high solar radiation; low relative humidity; moderate, but wide ranges of diurnal/nocturnal and seasonal temperatures; and high evaporation and transpiration rates (Taft 1980: 1; Tuan et al. 1973: 185–189). In the higher mountain ranges flanking the river valley, adjacent mesas, and foothills, subhumid and humid climatic conditions prevail. Average annual precipitation is higher, up to 30 inches; in contrast to the lower elevations of the region, not all available moisture is evaporated or transpired (Tuan et al. 1973: 192–195). Higher winds and lower seasonal temperatures occur here also.

Almost half of the average annual precipitation for the Rio Abajo falls from July to September or during the growing season (Tuan et al. 1973: 30, 33, 50). Precipitation fluctuates widely about the mean, and most summer rain is of high intensity and associated with thunderstorms. Average annual precipitation ranges from 7.25 inches at Peña Blanca to 8.31 inches at Las Cruces (Gabin and Lesperance 1977: 114, 327–364). Mean monthly (July) high temperatures for the Rio Abajo range from 76.2° F at Peña Blanca to 82.2° F at Las Cruces. Mean lows (December) for these two locations are 31.1° F and 37.6° F. The growing season

ranges from 189 days at Cochiti to 198 days at San Marcial (Bennett 1986: 46–47).

Winds in the summer are predominantly southerly, in the winter they are northerly, and in the spring northwesterly to southwesterly. March and April are the windiest months; Albuquerque averages 16 severe dust storms during this two-month period (Bennett 1986: 42–45; Tuan et al. 1973: 111).

Detailed climatic records before 1850 are limited, although tree-ring data provide some understanding of climate fluctuations and long-term patterns. Chronicles of Hispanic expeditions, missionary reports, and some government documents from the Colonial Period (A.D. 1540–1821) mention or describe some weather phenomena such as droughts, floods, severe cold, and deep snow. These environmental factors influenced or directly impacted many activities, notably travel, agriculture, livestock raising, warfare, hunting, and gathering. Drought and otherwise sporadic short-term and long-term precipitation were significant limiting factors and were interrelated with such environmental conditions as soil erosion, decreases in wildlife populations, changes in plant community species density and composition, and changes in surface water hydrology.

Extended cold winters, or shorter periods of below normal temperatures associated with high winds and snow (blizzards) and above normal snowfalls, had significant impacts. Events of these kinds commonly occurred during the “Little Ice Age,” which gripped New Mexico from about the mid-fifteenth to early 19th centuries. Adverse effects of this cold period included human fatalities, crop and livestock losses, and general unrest and suffering. The warming period and relatively frequent droughts that followed, especially from the 1860s to the 1950s, adversely impacted ranching economics, farming economics, and human population shifts and trends.

No comprehensive systemic study has been made of scientifically recorded climatic records, which date from the late 1840s to early 1900s in the Middle Rio Grande Basin. Associated data, such as stream flow records of the last 120 years or so, are just now being synthesized and analyzed. Comparative climatological data from tree-ring studies await attention as well.

In general, local climate and available construction materials dictated selection of building materials, with *terron*, or sod blocks, extracted from riverine wetlands, adobe bricks and/or stone used in the lower to mid-range elevations, and logs used in the higher, temperate, mountain locations.

Floods

Floods, due either to spring runoff resulting from the melting mountain snowpack or from intense summer rains, have played a significant environmental role in the Rio Grande’s hydrology and associated land-use activities during the historic period. Before the construction of major flood control structures on the upper Rio Grande and major tributaries in the 1930s, late spring and summer flooding of stream valleys was common. Maintenance of various climax plant communities was, in part, dependent on these seasonal floodwaters. This relationship will be discussed later in this chapter.

Reports of adverse impacts of these floods on Rio Grande Pueblos date as early as 1591, when De Sosa visited a flooded Santo Domingo village (White 1935: 12). Destruction of mission churches and farmlands was the most commonly documented impact of flooding during the Colonial Period.

Droughts

Probably the singlemost significant climatic factor affecting human populations negatively during the historic period was drought. Occurring regionwide, droughts damaged or destroyed crops and rangelands, devastated wildlife populations, and depleted water supplies. These impacts sometimes resulted in widespread loss of human life and the shifting of human populations. For example, the dry years of 1561–90, 1640, and 1663–69 contributed to or caused the abandonment of pueblos along the Galisteo drainage and in the Salinas Province (Abo, Quarai, and Gran Quivira) (Hackett 1937: 17; Schroeder 1972: 48; Vivian 1964: 153).

Historical documentation from the mid-seventeenth century to the late 19th century corroborates analyses of more recent detailed weather records, which suggest the occurrence of a major drought in the region every 20 to 25 years (Tuan et al. 1973: 64). These periodic droughts, increasing use of surface and ground waters, and intensive grazing have generally resulted in dramatic changes in the flora. These changes will be discussed later in this chapter.

Fire

Wildfires caused by lightning are a common phenomenon from July to September. American Indians used fire as one method of clearing the bosque for

cultivation. Woodland and range fires in the Rio Abajo were not suppressed until this century. In the prehistoric and historic periods, American Indians burned grasslands and woodlands to drive game animals to a location where they might be more easily killed, as well as to stimulate new plant growth (Cooper 1960: 138; Harris 1966: 416).

Woody shrubs and small tree species such as fourwing juniper, saltbush, and pinyon encroached on semi-desert grasslands near the valley as a result of fire suppression. Range fires usually kill small woody species, while grass regeneration is stimulated. Removal of dense stands of dry grasses by overgrazing also reduced available fuel for range fires and decreased competition from grasses, allowing propagation and growth of woody plants (Harris 1966: 416–418; Lymbery and Peiper 1983: 14–15). Interestingly, Josiah Gregg (1966: 202) in 1844 suggested that the grasslands of the Southwest would eventually be replaced by shrubs and trees due to suppression of range fires.

Infectious Diseases

The impact of introduced European diseases such as smallpox on American Indians has been relatively well documented in New Mexico; more Indians died of epidemics in the Colonial Period than from any other single cause. These serious maladies contributed significantly to unrest in the province, some of which resulted in several Pueblo revolts in the 1600s and increased raiding by nomadic Indian groups. The latter phenomenon was related to severe, extended drought conditions in the 1640s, 1660s, and 1770s to early 1780s, and it produced the most catastrophic periods of conflict and war in the Colonial Period. The annual Pueblo calendar of religious events was interrupted, and socioeconomic systems were fragmented due to these two environmental factors.

RESOURCE USE IN THE SPANISH COLONIAL AND MEXICAN PERIODS

The Spanish brought with them new technologies and many new domesticated plants and animals that had a decisive impact on Pueblo, Navajo, and Apache diet and landscape. Introduced livestock included sheep, goats, horses, mules, burros, oxen, cattle, hogs, and chickens. Introduction of metal tools such as the axe, which made cutting green wood easier and faster, as well as iron-tipped plows and weapons, had

an increasingly significant adverse impact over time on habitats of native fauna, flora, and soils. New cultigens included wheat, barley, cabbage, onion, lettuce, radish, cantaloupe, watermelon, and several species of fruit trees, as well as native Mexican Indian crops such as chile, cultivated tobacco, tomato, and new varieties of corn and beans. Some introduced non-cultigens, such as alferillo and horehound, became established in fields and other disturbed areas.

Spanish Colonial settlement land use patterns generally were similar to those of the indigenous, sedentary American Indians in the region (the Pueblos). Settlers chose land with good soils along or near water sources that could be used for ditch irrigation, domestic water, and livestock watering. The community land grant system used in northern New Mexico accentuated this pattern, with the principal concentration of settlers in a plaza, watered by an *acequia madre-sangrias*, fed by streams or springs, and with agricultural fields stretching between the *acequia madre* and the river or stream source. Irrigation farming of some lands led to salt buildup in soils, and clearing lands impacted local plants and animals.

Spanish villagers constructed dwellings at the upper ends of their fields, above the *acequias*, forming a settlement pattern resembling a string of beads, or *cordillera*. Often this occurred on the north slope of the river valley, to take advantage of solar radiation in the colder months.

Ejidors, or the common lands of grants, were the sources for wood (for building as well as fuel), building stone, and grasslands as summer forage for livestock. Hunting and gathering activities also occurred in the *ejidos*. Commonly hunted animals included deer, elk, and rabbits. Fuelwood, building stone and wood, medicinal plants, and edible plants were collected in these areas as well. The cycle of adverse impacts on biotic communities in these areas, which would greatly accelerate in the Territorial Period, was put into motion in the Spanish Colonial era.

After the Spanish-Comanche Peace of 1786 gave some respite to conflicts with nomadic Indians, the *ciboleros*, or buffalo hunters, who had adopted the annual fall hunting tradition of the Pueblos, increased their trips onto the eastern plains from the Middle Rio Grande Basin. An estimated 12,000 bison were harvested annually from this time into the first half of the 19th century. Combined with the market for buffalo robes created by Anglo traders after 1821, virtually all the buffalo were exterminated or driven from the eastern plains of New Mexico.

Limited mining in the Colonial Period by both Spaniards and Pueblos impacted local areas. The best known of these locales are the turquoise and lead mines in the Cerrillos area and north of the Sandia Mountains. Pinon, juniper, and oak were cut for "smelting" fuelwood, mining timbers, and structures. Some local water pollution was generated by these mining activities.

During the Mexican Period, some of the effects of settlement and land use on the natural environment were recorded by both government and ecclesiastical officials. Overgrazing around old settlements and nearby valley and upland rangelands, begun in the Colonial Period, intensified. Some of the choice grazing areas in the region were cienegas and other wetlands, which were heavily impacted by livestock during this period. Livestock trails turned into linear arroyos, and silt-laden run-off increased.

Padre Martinez of Taos complained about the effect of both hunting and trapping on the wild animal populations of the traditional use areas of Taos Pueblo and the Jicarilla Apaches. Trappers, including some Mexican and newly arrived Franco- and Anglo-Americans, began intensively harvesting beaver pelts in the rivers and streams throughout northern, central, and southwestern New Mexico in the early 1820s. Beaver populations were quickly decimated overall in the region and even extirpated in some streams; in response, the Mexican government issued a moratorium on trapping in 1838.

Anglo-American traders, such as the Bent brothers, directly contributed to the decimation of fur animals across southern Colorado and northern New Mexico. American Indians, especially nomadic groups such as the Plains Indians, eagerly hunted and trapped to obtain goods offered by traders. With this focus on hide harvesting and processing, day-to-day and season-to-season elements of their way of life were disrupted.

Around the gold, silver, and copper mines in the Ortiz, Sandia, and Jemez mountains, the land was denuded of trees by wood cutters to make support timbers and charcoal for the mines. The relatively sharp increase in livestock numbers, especially sheep, during this period was due to the growth in mining markets to the south in Mexico (and later California). This intensive and widespread grazing resulted in loss of vegetative cover in various locales. Grass shortages on Spanish land grants led, in part, to encroachment of Mexican flocks and herds on Pueblo crop and range lands, erosion of hillsides, and the siltation of river and stream beds.

RESOURCE USE IN THE TERRITORIAL PERIOD

The arrival of relatively large numbers of Anglo-American military personnel, ranchers, and settlers, beginning in 1846, had a significant impact on New Mexico's environment. Although these groups did not introduce many new domesticated plants and animals, their implementation of more intensive land-use patterns, coupled with a new technology, increasingly contributed to the ongoing erosion of hillsides and siltation of river beds, as well as the extermination or reduction of several animal species. Military forts, mining camps, and railroad construction made heavy use of natural resources such as trees for both building and fuel supplies, harvesting of native grasses for "hay," and killing local game, such as grizzly bears, black bears, bighorn sheep, deer, elk, pronghorn antelope, and several species of birds for food and sport. Major stream pollution occurred at many mining sites, killing associated fauna and flora and poisoning water supplies. Many of these mining sites were abandoned, leaving open pits and shafts and toxic spoil deposits. Air quality was also negatively impacted by the railroad and mine smelters. These technologies were the first serious sources of noise pollution in the Territorial Period.

Early saw mills in or near such settlements as Santa Fe, Taos, and Albuquerque resulted in the first extensive clearcutting of forests. As a result, soil erosion was accelerated at these locales, and habitat loss contributed to the reduction of game animal populations.

The growth of the range cattle industry in New Mexico after the Civil War led to increased grazing of grasslands. Cattlemen employed a strategy of securing sections of the public domain having water sources to control larger areas for grazing. During the mid-1880s, a severe winter followed by a drought and another cold winter led to the massive reduction in livestock numbers and ultimately the range cattle industry. After the introduction of barbed wire and windmills, open range gave way to fenced pastures. Overgrazing along streams, at other wetland sites, and at windmill tanks occurred.

Anglo ranchers, unlike Native and Hispano Americans, suppressed range fires. This action, combined with overgrazing, caused native plant species such as broomweed, cholla, prickly pear cactus, sagebrushes, and less desirable grasses to spread and increase on pristine grasslands. The exotic Russian thistle and several introduced grasses also prolifer-

ated. Consequently, the carrying capacity of New Mexico's rangelands was reduced significantly during this period.

Intensified irrigation farming impacted stream hydrology and increased salinization and waterlogging of soils in the Middle Rio Grande Basin in the late 19th and early 20th centuries. This resulted in the loss of thousands of acres of agricultural land by the early Statehood Period and was a factor leading to the creation of the Middle Rio Grande Conservancy District in 1926. The drainage systems, dams and reservoirs, and levees which followed produced a new set of environmental problems, such as a rapid drop in shallow ground waters, flooding of habitat, and diminution of native *bosques*, all of which have only recently begun to be addressed.

Toward the end of the 19th century, homesteaders claimed and farmed much of the public domain, with population growth centered in central and eastern New Mexico. They plowed virgin shortgrass plains and dry-farmed crops such as broom corn, milo, maize, and pinto beans. These newcomers also raised livestock on their small claims, which generally contributed to overgrazing, and in some areas these land-use practices contributed to the environmental impacts which resulted in the Dust Bowl of the 1930s.

Railroads were both influenced by and, in turn, affected the environment in several adverse ways. Topography, in particular the requirement for low grades and the need for water for steam engines every ten miles, played a significant role in the choice of route. Rail routes generally followed stream valleys, causing damage to riparian biotic communities and polluting streams. Train engines were often the cause of range or forest fires (ignited by ashes and sparks) and other environmental changes.

Railroad construction also impacted forests (mainly for ties and locomotive fuel) and streams (siltation from exposed soils). Animal populations were subjected to additional pressures as commercial hunters harvested meat animals to feed the railroad construction crews. Deer, pronghorn antelope, and elk were the main game species; elk populations were eradicated in some areas.

Hot springs, long visited by both American Indians and Hispanics, were used for medicinal and recreational purposes; often Anglo promoters built hotels or spas near the springs, and some lobbied successfully for a railroad connection. Cold water springs were tapped for irrigation, domestic use, or livestock water. Many springs were impacted, both

in terms of water quality and quantity. Some no longer flow today due to intensive mining of water and periodic droughts.

Commercial, subsistence, and sport hunters during the late 19th and early 20th centuries had sharply reduced or exterminated populations of native game animals such as pronghorn antelope, elk, bighorn sheep, and Rio Grande turkey. This over harvesting resulted from the lack of regulatory game laws, more efficient firearms and ammunition, an increasing number of hunters, and a philosophy that there would always be wild animals of any kind to hunt. In response, the New Mexico Game and Fish Department was created by the territorial legislature in 1904. Both state and federal regulatory laws were subsequently passed. These regulatory actions supported by hunters went on to help restore populations of many native game species.

RESOURCE USE IN THE STATEHOOD PERIOD

During the preceding period farmers, ranchers, and the general hunter population had killed large numbers of predators, notably the grizzly bear, gray wolf, Mexican wolf, coyote, and mountain lion. Beginning in the second decade of this century state and federal agencies joined in an effort to exterminate the grizzly and the two wolf sub-species. By the 1930s, they had almost eradicated two of the three; a few Mexican wolves survived in extreme southwestern New Mexico until the 1950s.

Under the management of federal and state agencies, several animal species (bighorn sheep, elk, and wild turkey) were reintroduced to wildlife preserves established at various locations in the 1920s through 1940s. At a later time the Game and Fish Department introduced the ibex, barbary sheep, and oryx. Some wildlife specialists view these animals as detrimental to indigenous species such as the bighorn sheep.

Other exotic animal species and many plants were introduced and naturalized during this period and became, or have become, ecological-economical problems by the 1950s. These species were either inadvertently or purposefully introduced. Some of the introduced animals included the Norway rat, house mouse, burros, horses, and several species of amphibians and fish. The most troublesome plants are tree-of-heaven, Russian olive, Russian thistle (tumbleweed), Siberian elm, and tamarisk.

During the New Deal, a massive effort at reforestation and environmental conservation was initiated

through several programs, most notably the Civilian Conservation Corps (CCC), the Grazing Service, and the Soil Conservation Service. The Grazing Service was merged with the General Land Office and became the Bureau of Land Management in 1934.

With the passage of the Antiquities Act of 1906, a number of outstanding natural and archeological areas were set aside for preservation management by the National Park Service and the Forest Service. Also, the state legislature created the New Mexico Parks Commission, later renamed the State Park and Recreation Commission, and some "natural" areas were established under its administration.

In the last three decades several federal and state agencies, as well as private organizations, have assumed responsibilities for restoring and managing indigenous ecocultural resources through bioremediation, restoration, and/or preservation. Progress has been made, but much remains to be done to restore overgrazed rangelands and riparian areas, to stop leaching of toxic materials from historic mining sites, to arrest soil erosion in intensively grazed and logged locations, to increase populations of rare and endangered plants and animals, to foster continuance of traditional ecocultures, and to improve water quality in all of these areas. The burgeoning population and attendant development contribute to and exacerbate the adverse environmental impacts of the past and produce new problems for all New Mexicans today.

LITERATURE REVIEW

Only those sources, published and unpublished, that specifically focus on the environmental history of the Middle Rio Grande Basin are briefly reviewed here. Generally, little investigation has been directed at the interrelationship of humans and their biological-physical environment. Most striking is the lack of a reconstruction of the climatic regime and its impact during the historic period. Although fire suppression is usually regarded as adversely affecting species composition, in fact the relationship of natural and incendiary fires to biotic communities is not sufficiently understood. Some recent fire history studies, such as those by Baisan (1993) and Foxx (1981) for the Sandia and Manzano mountains do, however, provide starting points and direction.

No serious attempts have been made to identify and document all introduced plant species into the region and their impact. There are, however, many

studies on the environmental history and ecological impact of tamarisk (Campbell and Dick-Peddie 1964; Crawford et al. 1993; Harris 1966; Robinson 1958, 1965).

General histories of human populations and the river are found in: Baker et al. (1988); Calvin (1934); Gilpin (1949); Kelley (1952), Sargeant (1987), Sargeant and Davis (1986), Schroeder (1968, 1972, 1979), Tucker (1992), and Welsh (1985). Eastman et al. (1971) have published a paper on attitudes toward land, and Oberg (1940) focused on cultural factors and land-use planning.

Finally, there are a number of archival guides and references for the study region: Beers (1979), Bureau of Land Management (1979), Burger (1990), Chavez (1957), Colley (1972), Gallacher (1986), Jackson and Teeple (1978), Jenkins, Simmons and Martinez (1967), Jenkins (1968, 1969, 1970), National Archives and Records Service (1973), O'Connor (1989), Rex (1991), and Tyler (1984).

Data on human demography in the historic period for central and northern New Mexico include:

Pueblo: Dozier (1983), Earls (1992), Simmons (1979a and b), Thornton (1987);

Spanish: Bailey and Haulman (1977), Carroll and Haggard (1942), Jones (1979), Nostrand (1992), Olmstead (1975, 1981) Tainter and Levine (1987); and

Anglo: U.S. Census Bureau (1850–1990).

Overviews of the late prehistoric-historic Pueblos in the basin, which address settlement patterns and land-water use, are found in Abbink and Stein (1977), Cordell (1979), and Riley (1987). Hodges (1938) reported on irrigation water supply for each Pueblo. DuMars et al. (1984) have published an in-depth study of Pueblo water rights. Ford (1972) has done a detailed view on the regulatory role of ritual systems in counteracting environmental crises and stressful periods of Eastern Pueblos and their environment. Studies on the environmental adaptations of Zia and Tewa Pueblos also have been published (Euler 1954; Ford 1972, 1987). An early 20th-century study of the relationship of Rio Grande Pueblos and valley physiography was conducted by Hewett et al. (1913). Hewett and Dutton (1945) published a general study of Pueblos and their physical surroundings. Zubrow (1974) produced a published study of the interrelationships of population, climate, and contact with Euroamericans on the historic Pueblos. His work, including construction of a deductive model, found that from post-1800 to the recent past the Pueblos

experienced some resource-related problems due to Spanish and Anglo encroachment and resource use. The historical data used by Zubrow, although limited, corroborate Puebloan subsistence difficulties during this period.

Many studies on the interrelationships of Hispanic and Anglo land-water use and management from 1846 to the recent past have been published. Briggs and Van Ness (1987), deBuys (1985), Harper et al. (1943), and Hernandez et al. (1971) have addressed Hispanic land grantees and their resources. Meyer (1984) has published an in-depth overview of Hispanic use of water, focusing on community use, water rights, irrigation, and litigation. Other settlement pattern-resource use studies have been conducted by Kelley (1955), Maes and Fisher (1937), Moir et al. (1971), Simmons (1972, 1974), Sunseri (1979), Tainter and Levine (1987), and Westphall (1983). Historic management studies have been produced by Rothman (1992), among others.

Many reports and papers on water control and management exist for the basin. Some of the general ones, including treatment of problems and issues, are Albuquerque National Trust and Savings Bank (1936), Burkholder (1928), Clark (1987), Dortignac (1956, 1963), Follansbee and Dean (1915), Forsling (1950), Hay (1972), Linford (1956), Nickerson (1945), and Wortman (1971). Follett (1898) and Yeo (1910) wrote a report on the conditions of water control systems in the Middle Rio Grande with emphasis on water use facilities and irrigation. Welsh (1985) has published a paper on management of the Middle Rio Grande Basin water resources by the U.S. Corps of Engineers.

The earliest written descriptions of the Middle Rio Grande Basin, albeit general, were, of course, the Spanish, beginning with Coronado in 1540 and others in the late 1500s (Hammond and Rey 1940, 1966). Other early colonial (to 1680) observers include Vargas (Bailey 1940; Kessell and Hendricks 1992), Benavides (1965), and Hodge et al. (1945). Observations on the general environment from Spaniards in the 18th and early 19th centuries are found in Adams (1954), Adams and Chavez (1956), Carroll and Haggard (1942), Hackett (1937), Kessell (1992), and Simmons (1982).

There are numerous journals and diaries of Anglo explorers, settlers, military personnel (Abert 1962; Bell 1965; Calvin 1968; Davis 1982; Frazer 1981; Gregg 1966, Pattie 1966; Wislizenus 1969) and state and federal resource investigators (Bailey 1913; Bryan 1927,

1928; Burkholder, 1928; Cockerill et al. 1939; Cooperrider and Hendricks 1937; Follansbee and Dean 1915; Hodges 1938; Ligon 1927; Maes and Fisher 1937; Matthew 1897; Middle Rio grande Conservancy District 1928; Poore 1893; Pynch et al. 1911; and Wooton 1908) describing landscape, water, fauna, flora, etc., dating from the mid and late 1800s and the early 1900s. These provide the first relatively detailed descriptions of fauna and flora, floods, grazing, farming, and mining in the region. Some include the first illustrations, drawings, lithographs, and photographs of fauna, flora, farming activity, etc. The first detailed maps of the region appear with early U.S. Army reports. Scurlock (1988b, 1988c, 1993a, 1993b) has used many of these sources in recent publications.

A major study of irrigation system development from the late prehistoric period to 1945 in the Rio Grande Valley was prepared by Wozniak (1987) for the Historic Preservation Division. Evidence is presented to show that irrigation was a major influence in the "development and character of New Mexico society in the Rio Grande Valley from 1700 to the early 1900s." Wozniak's report also deals with government reclamation projects and related socioeconomic changes since the early 1900s. Simmons (1972) has addressed Spanish irrigation practices for the basin. A major unpublished study on water use and development in New Mexico after 1846 was written by Linford (1956), including discussion of federal and state water projects.

A voluminous work on historic water use in the state, primarily on the sociopolitical and management aspects, was authored by Ira Clark (1987). R.E. Clark (1958) has produced a paper on water law and traditional Pueblo and Hispanic communities. Reports on water statistics, irrigation, drainage, etc., have been published by Burkholder (1928), Follett (1898), Middle Rio Grande Conservancy District (1928), Poore (1893), Pynch (1911), Welsh (1985, 1987), and Yeo (1910).

Fritts (1965), Gabin and Lesperance (1977), Scurlock (1994), Swan (1977), Taft (1980), Tuan et al. (1973), and Zubrow (1974) have all published reports on historic climate and human interrelationships with climatic events in central New Mexico. Zimmerman Library has many volumes of published U.S. Weather Bureau records from the late 1800s for the region.

River hydrology and morphology, including floods, are found in Bryan (1927, 1928), Bowen and Sacca (1971), Carter (1953), Calkins (1937), Crawford

et al. (1993), Sargeant (1987), Sargeant and Davis (1986), and Scurlock (1993b). Land grant records, early government documents, and early maps, photographs, aerial photos, etc. contain untapped information on these topics.

Historic and recent flora are treated in Allen (1984), Bailey (1913), Brown (1982), Cooper (1960), Crawford et al. (1993), Dick-Peddie (1993), Freehling (1982), Gross and Dick-Peddie (1979), Harris (1966), Hink and Ohmart (1984), Manthey (1977), Leopold (1951), Minckley and Rinne (1985), Robinson (1958), Scurlock (1988a, 1993a and b), Van Cleave (1935), Watson (1912), and Wislizenus (1969). Data on the use of indigenous plants by the Pueblos are found in Hewett and Dutton (1945). Spanish use of native woods is found in Jones (1932).

The only historical vegetative studies of the research region using paired photographs have been done by Klett et al. (1984) and Sallach (1986). There are, however, several studies of the surrounding region that will serve as models for paired photo research in the Middle Rio Grande Basin (Athearn 1990; Baars and Buchanan 1994; Bureau of Land Management 1979; Humphrey 1987; Rogers 1982, 1984; Veblen and Lorenz 1991; Zaidliez 1979). A major drawback in using historic photographs is that even the earliest images date after major vegetation changes caused primarily by intensive grazing and fire suppression had occurred.

Faunal studies of protohistoric sites in the basin contain data on vertebrate species present and their usages by American Indians. A few of the more important ones are Akins (1987), Crawford et al. (1993), Marchiando (1977), Sublette et al. (1990), and Young (1980). For the historical period, there are data on mammals recorded by Allen (1903), Bailey (1971), Carroll and Haggard (1942), Gregg (1966), Findley et al. (1975), Ligon (1927), Linford (1967), Matthew (1897), Moore (1986), Pattie (1966), and Warren (1942). Historical data on birds are found in reports by Abert (1962), Bailey (1928), Freehling (1982), Henshaw (1875), Hubbard (1978), and Ligon (1927, 1961). The works of Koster (1957) and Sublette et al. (1990) contain historical data on Rio Grande fish, as does Crawford et al. (1993).

Livestock numbers and grazing are covered by Baxter (1987), Baydo (1970), Carlson (1969), deBuys (1985), Denevan (1967), Eastman and Gray (1987), Rothman (1989), Rowley (1985), Smith (1953), and Wooton (1908). A survey of ranches and farms is found in Cockerill (1959) and Cockerill et al. (1939).

Siltation and erosion problems related to intensive grazing are discussed in Bryan (1927), Cooke and Reeves (1976), Denevan (1967), Dortignac (1956, 1963), Harper et al. (1943), Nickerson (1945), Pynch et al. (1911), Wooton (1908), and Yeo (1910).

This investigator (Scurlock 1993b) has written an overview of environmental history of the Rio Abajo (the Rio Grande Basin from La Bajada-Cochiti to San Marcial) for the Biological Interagency Team of the Middle Rio Grande Bosque Management Project (Crawford et al. 1993). Scurlock (1988c; 1993c) has also published papers on the historic environment of the Camino Real and changes in the Middle Rio Grande bosque, and co-authored two regional studies of northwest and southwest New Mexico which included some environmental history (Scurlock 1988a; 1991). A monograph manuscript of an overview on the environmental history of pinyon-juniper in the Southwest was recently completed and is being reviewed for possible publication (Scurlock 1993a).

RESEARCH NEEDS, STRATEGIES, AND GOALS

Extant and new historical and archeological data may provide the environmental context and baselines to address the following problems:

1. Need a better understanding of the long-term responses of ecosystem components—soils, nutrients, water, flora, and mycorrhizae—to past and present perturbations caused by climate change, fire, herbivore grazing, irrigation and dry farming, logging, fuelwood harvesting, and other human activities. Secondarily, these historical data will shed light on how such responses influence ecosystem dynamics, stability, and productivity of upland communities.
2. Need better understanding of upland biotic communities, including the historic, spatial, and temporal interrelationships with fluvial ecosystems.
3. Need better understanding of how humans adapted to changing environmental conditions, both “natural” and human-induced, and to determine when and how these perturbations occurred and what the consequences were. These data will be used to determine sustainability of traditional land-water activities today and more importantly in the future.
4. Need better understanding of the evolution of basin ecosystems in terms of human interactions related to cultural elements—“world view,” use

of resources, and economics—and how these land-water use histories relate to conflicts between specific groups. Collected data for use in planning future management for sustainability of resources as related to differing group views will afford a more sound basis for such decision-making.

To assist in addressing these four major problems, the following research sub-goals will be explored:

- a. Reconstruction of historic climatic regimes for the overall basin and specific locales.
- b. Reconstruction of morphological dynamics of the Rio Grande and major tributaries related to floods and human-use management.
- c. Reconstruction of water flow data and interrelationships with climatic fluctuations and human use.
- d. Reconstruction of historic fire occurrence spatially and temporally.
- e. Reconstruction of human-induced changes in ecosystem components.
- f. Reconstruction of overall and site-specific spatial-temporal grazing history and impacts.
- g. Reconstruction of spatial-temporal overall and site-specific farming history.
- h. Reconstruction of changes in plant and animal communities and particular species populations over time related to human use, climatic change, and exotic species introductions.
- i. Reconstruction of human responses to these changes.
- j. Reconstruction of adaptations of various groups to the same subregional, or area, environments.
- k. Examination of the similarities and/or differences in Pueblo agricultural techniques and production along streams such as the Rio Grande and Las Huertas Creek.
- l. Delineation of eco-cultural areas based on spatial-temporal distributions of specific groups related to identifiable ecosystems.
- m. Comparisons between the exploitation strategies of different populations, e.g. Hispano and Anglo livestock raisers utilizing the same resource area, as well as the impacts of utilization.
- n. Construction of spatial-temporal models of ecosystems, including humans as a major factor in the dynamics and change of these systems (i.e., the Santa Fe River, Rio Puerco, Las Huertas and Tijeras Arroyos, and sections of the Rio Grande,

such as the Bosque del Apache and Isleta Pueblo areas [including the wetlands]).

Models

The following four spatial and temporal models of the Middle Rio Grande Valley historical ecosystem will be tested using data collected and analyzed. The resulting revised models will provide a context for better bioremediation, evaluation of sustainability of land-use practices, and development of appropriate management programs.

Model I: Middle Rio Grande Basin in 16th century

Historic river hydrology-morphology:

- Perennial flows; relatively deeper, larger volume of water.
- Transport of relatively low sediment load.
- Braided, slightly sinuous, aggrading, shifting sand substrate.
- Overbank flooding with two peaks—April to early June (snowpack melt, highest water flow); August to September (intense precipitation on watershed).
- Shifting river channel and movement across floodplain (avulsion).
- Island and sand bar formation-destruction.

River-floodplain biological-ecocultural components:

- Grass meadows, *ciénegas*, *charcos* (ponds or small lakes).
- Varied, changing age structures of cottonwood-willow stands.
- Wildlife diverse and relatively abundant.
- Some life forms present—wolf, river otter, mink, whooping crane, Rio Grande turkey, shovelnose sturgeon, and 11 other fish species (now extinct).
- Limited Pueblo diversion of river for irrigation.
- Ca. 30,000 acres of floodplain under Pueblo cultivation.

Model II: Middle Rio Grande Basin in 18th to mid 19th centuries

Historic river hydrology-morphology:

- Somewhat decreased stream flows.
- Flow widening and becoming more shallow.
- Braided, sinuous, increasing aggradation.
- Overbank flooding and avulsion more frequent and severe.
- Increased frequency of channel shifting resulting from intense floods.

- River banks and islands less stable.
- Increasing sediment load due to various land-use practices.

River-floodplain biological-ecocultural components:

- More fragmented and reduced stands of cottonwood-willow communities due to intense floods.
- Increased alkalinity and waterlogging of soils.
- Increased numbers of grass meadows, *cienegas*, and *charcos*.
- Less stable and decreasing populations of faunal communities.
- Increase to ca. 100,000 acres under cultivation by Pueblos and Hispanos.

Model III: Middle Rio Grande Basin in late 19th century to early 20th century

Historic river hydrology-morphology:

- Continued decrease in flows, increase in sediment load, and aggradation of river.
- Flood frequency and intensity increased.
- Some scouring and incising of river channel due to floods.
- Increased soil alkalinity and waterlogging.
- Rising water table, then lowering water table.

River-floodplain biological-ecocultural components:

- Highest (?) number of wetlands and associated plant communities, then severe reduction to lowest in historic period.
- Cultivated acreage increased to perhaps 125,000 acres by Euroamericans and Pueblos, then decreased to 35,000 acres due to environmental changes.
- Increased alkalinity and waterlogging of valley soils.
- A number of wildlife species extirpated.
- Less stability and severe decrease in wildlife populations.

Model IV: Middle Rio Grande Basin in mid to late 20th century

Historic river hydrology-morphology:

- Decrease in sediment load and aggradation of river.
- Flood frequency and intensity decreased dramatically due to construction of major dams.
- Continuing lowering of water table.
- Channel straightened and bermed, channel shifts virtually halted, and banks stabilized.

River-floodplain biological-ecocultural components:

- Cultivated acreage increased to 58,000 acres.
- Floodways cleared and channel modified.
- Continued reduction of wetlands.
- Construction of several ponds.
- Some wildlife populations increased.
- A few exotic plant and fish species introduced.
- A few wildlife species extirpated.

BENEFICIARIES OF RESEARCH

In addition to potential data uses by various public ecocultural resource management personnel and agencies, this study would be useful to a myriad of other basin communities and organizations: Pueblos, Hispanic land grant associations, the Middle Rio Grande Conservancy District, universities and schools, environmental groups, and private firms and individuals involved in Middle Rio Grande Basin research. Potential uses include evaluating current resource use and management, planning for bioremediation of specific locales or areas, evaluating sustainability of current land-use practices, locating field trip-study area sites, and identifying critical environmental issues.

REFERENCES

- Abbink, Emily K.; Stein, John R. 1977. An historical perspective on adaptive systems in the middle Rio Grande. In: Archeological investigations in Cochiti Reservoir, New Mexico, vol. 1, edited by Jan V. Biella and Richard C. Chapman, Office of Contract Archeology, University of New Mexico, Albuquerque, NM. 154-155 pp.
- Abert, J.W. 1962. Abert's New Mexico report, 1846-47. Horn and Wallace, Albuquerque, NM.
- Adams, Eleanor B. (editor) 1954. Bishop Tamaron's visitation of New Mexico, 1760. Historical Society of New Mexico Publications in History No. 15, Albuquerque, NM.
- Adams, Eleanor B.; Chavez, Fray Angelico (translators and annotators) 1956. The missions of New Mexico, 1776: A description by Fray Francisco Atanasio Dominguez with other contemporary documents. University of New Mexico Press, Albuquerque, NM.
- Akins, Nancy J. 1987. Animal utilization in the Middle Rio Grande Valley area. In: Secrets of a city: Papers on Albuquerque area archaeology in honor of Richard A. Bice. Papers of the Archaeological Society of New Mexico: 13. Ancient City Press, Santa Fe, NM.

- Albuquerque National Trust and Savings Bank. 1936. Valley development number. Albuquerque Progress. 3(7).
- Allen, Craig D. 1984. Montane grasslands in the landscape of the Jemez Mountains, New Mexico. University of Wisconsin, Madison, WI. Master's thesis.
- Allen, J.A. 1903. List of mammals collected by Mr. J.H. Batty in New Mexico and Durango, with descriptions of new species and subspecies. Bulletin of the American Museum of Natural History. 19: 587-612.
- Athearn, Frederic J. 1990. A view to the past—A window to the future: A guide to photodocumenting historic places. Bureau of Land Management Colorado State Office Cultural Resources Series Number 30, Denver, CO.
- Baars, Donald L.; Buchanan, Rex C. 1994. The canyon revisited: A rephotography of the Grand Canyon 1923/1991. University of Utah Press, Salt Lake City, UT.
- Bailey, David T.; Haulman, Bruce E. 1977. Ethnic differences on the Southwestern United States frontier, 1860. In: The frontier: Comparative studies, edited by David Harry Miller and Jerome O. Steffen, University of Oklahoma Press, Norman. 243-247 pp.
- Bailey, Florence Merriam. 1928. Birds of New Mexico. New Mexico Department of Game and Fish, Santa Fe, NM.
- Bailey, Jessie Bromilow. 1940. Diego de Vargas and the reconquest of New Mexico. University of New Mexico, Albuquerque, NM.
- Bailey, Vernon. 1913. Life zones and crop zones of New Mexico. U.S. Department of Agriculture: North American fauna 53, Washington, D.C.
- Bailey, Vernon. 1971. Mammals of the Southwestern United States. Dover Publications, New York.
- Baisan, Christopher H. 1993. Sandia/Manzano fire history progress report. Laboratory of Tree-Ring Research, University of Arizona, Tucson, AZ.
- Baker, Robert D.; Maxwell, Robert S.; Treat, Victor H.; Dethloff, Henry D. 1988. Timeless heritage: A history of the Forest Service in the Southwest. U.S. Department of Agriculture, Forest Service, Washington, DC.
- Bancroft, Hubert Howe. 1889. History of Arizona and New Mexico 1530-1888. The History Company, San Francisco, CA.
- Baxter, John O. 1987. Las carneradas: Sheep trade in New Mexico. University of New Mexico Press, Albuquerque, NM.
- Baydo, Gerald Robert 1970. Cattle ranching in Territorial New Mexico. University of New Mexico, Albuquerque, NM. Ph.D. dissertation.
- Beers, Henry Putney. 1979. The records of New Mexico. In: Spanish and Mexican records of the Southwest. University of Arizona, Tucson.
- Bell, William A. 1965. New tracks in North America: A journal of travel and adventure whilst engaged in the survey for a southern railroad to the Pacific Ocean during 1867-8. Horn and Wallace Publishers, Albuquerque, NM.
- Benavides, Alonso de. 1965. The memorial of Fray Alonso de Benavides. Translated by Mrs. Edward E. Ayer. Horn and Wallace Publishers, Albuquerque, NM.
- Bennett, Iven. 1986. Frost. In: New Mexico in maps, Jerry L. Williams (ed), University of New Mexico Press, Albuquerque, NM. 46-47 pp.
- Bowen, Joanne; Sacca, Mary Lynn. 1971. Bernalillo and the Rio Grande. Unpublished manuscript, Beloit College, Beloit, Wisconsin, IL.
- Briggs, Charles L.; Van Ness, John R. (editors) 1987. Land, water, and culture: New perspectives on Hispanic land grants. University of New Mexico Press, Albuquerque, NM.
- Brown, David E. (editor) 1982. Biotic communities of the American Southwest-United States and Mexico. Desert Plants. 4 (1-4): 1-342.
- Bryan, Kirk. 1927. Channel erosion of the Rio Salado, Socorro County, New Mexico. U.S. Geological Society Bulletin. 790: 15-19.
- Bryan, Kirk. 1928. Historic evidence on changes in the channel of Rio Puerco. Journal of Geology. 36(3): 265-282.
- Bureau of Land Management. 1979. Historical comparison photography: Missouri Breaks, Montana. Montana State Office, Billings, MT.
- Burger, Barbara Lewis 1990. Guide to the holdings of the still picture branch of the National Archives. National Archives and Records Administration, Washington, D.C.
- Burkholder, Joseph L. 1928. Report of the Chief Engineer, Middle Rio Grande Conservancy District, New Mexico. 3 vols. Albuquerque, NM.
- Calkins, Hugh G. 1937. Destruction of the villages at San Marcial. U.S. Department of Agriculture, Soil Conservation Region 8 Bulletin No. 38, Conservation Economics Series No. 11, Albuquerque, NM.
- Calvin, Ross 1934. Sky determines, 1st edition. The MacMillan Co., New York, NY.

- Calvin, Ross (editor) 1968. Lieutenant Emory reports. University of New Mexico Press, Albuquerque, NM.
- Campbell, C.J.; Dick-Peddie, W.A. 1964. Comparison of phreatophyte communities on the Rio Grande in New Mexico. *Ecology*. 45(3): 492–502.
- Carlson, Alvin Ward. 1969. New Mexico's sheep industry 1850–1900: Its role in the history of the territory. *New Mexico Historical Review*. 44(1): 25–49.
- Carroll, H. Bailey; Haggard, J.V. (translators and editors) 1942. Three New Mexico chronicles: The exposition of Don Pedro Bautista Pino, 1812; the Ojeada of Lic. Antonio Barreiro, 1832; and Don Agustin de Escudero, 1849. The Quivira Society, Albuquerque, NM.
- Carter, Rufus H. Jr. 1953. A historical study of floods prior to 1892 in the Rio Grande watershed. M.A. Thesis, University of New Mexico, Albuquerque, NM.
- Chavez, Fray Angelico. 1957. Archives of the Archdiocese of Santa Fe, 1687–1900. Academy of American Franciscan History, Washington, D.C.
- Clark, Ira G. 1987. Water in New Mexico: A history of its management and use. University of New Mexico press, Albuquerque, NM.
- Clark, R.E. 1958. Water law institutions and the community. *New Mexico Quarterly*. 28(2–4): 97–112.
- Cockerill, P.W. 1959. A statistical history of crop and livestock production in New Mexico. *New Mexico State University Agricultural Station Bulletin No. 438*, Las Cruces, NM.
- Cockerill, P.W.; Hunter, Byron; Pingrey, H.B. 1939. Type of farming and ranching areas in New Mexico: Part II. *Agricultural Experiment Station Bulletin No. 267*, New Mexico College of Agriculture and Mechanic Arts, Las Cruces, NM.
- Colley, Charles C. (compiler) 1972. Documents of Southwestern history: A guide to the manuscript collections of the Arizona Historical Society. Arizona Historical Society, Tucson, AZ.
- Cooke, Rovalt U.; Reeves, Richard W. 1976. Arroyos and environmental change in the American Southwest. Clarendon Press, Oxford.
- Cooper, Charles C. 1960. Changes in vegetation, structure and growth of Southwestern pine forests since white settlement. *Ecological Monographs*. 30(2): 129–164.
- Cooperrider, C.K.; Hendricks, B.A. 1937. Soil erosion and stream flow on range and forest lands of the upper Rio Grande watershed in relation to land resources and human welfare. U.S. Department of Agriculture, Washington, D.C.
- Cordell, Linda S. 1979. A cultural resources overview of the middle Rio Grande Valley, New Mexico. U.S. Department of Agriculture, Forest Service, Southwestern Region, Albuquerque, NM.
- Crawford, Cliff et al. 1993. Middle Rio Grande ecosystem: Bosque Biological Management Plan. U.S. Fish and Wildlife Service, Albuquerque, NM.
- Davis, W.H.H. 1982. *El gringo: Or New Mexico and her people*. University of Nebraska Press, Lincoln, NE.
- deBuys, William. 1985. *Enchantment and exploitation: The life and hard times of a New Mexico mountain range*. University of New Mexico Press, Albuquerque, NM.
- Denevan, William M. 1967. Livestock numbers in nineteenth century New Mexico and the problem of gullying in the Southwest. *Annals, Association of American Geographers*. 57 (4): 691–703.
- Dick-Peddie, William A. 1993. *Vegetation of New Mexico: Past, present and future*. University of New Mexico Press, Albuquerque, NM.
- Dortignac, E.J. 1956. Watershed resources and problems of the upper Rio Grande basin. Rocky Mountain Forest and Range Experiment Station, U.S. Department of Agriculture, Forest Service, Fort Collins, Colorado, CO.
- Dortignac, E.J. 1963. Rio Puerco: Abused basin. In *Aridity and Man*, edited by C. Hodge and P.C. Duisberg, American Association for the Advancement of Science Publication No. 74, Washington, D.C. 507–515 pp.
- Dozier, Edward P. 1983. *The Pueblo Indians of North America*. Waveland Press, Prospect Heights, Illinois.
- DuMars, Charles T.; O'Leary, Marilyn; Dutton, Albert E. 1984. *Pueblo Indian water rights*. University of Arizona Press, Tucson, AZ.
- Earls, Amy C. 1992. Raiding, trading and population reduction among the Piro Pueblos, A.D. 1540–1680. In: *Current research on the late prehistory and early history of New Mexico*, edited by Bradley J. Vierra and Clara Gualtieri, New Mexico Archaeological Council Special Publication 1, Albuquerque, NM. 11–20 pp.
- Eastman, Clyde; Gray, James R. 1987. *Community grazing: Practice and potential in New Mexico*. University of New Mexico Press, Albuquerque, NM.
- Eastman, Clyde; Carruthers, Garrey; Liefer, James A. 1971. Evaluation of attitudes toward land in north-central New Mexico. *Agricultural Experiment Station Bulletin No. 577*, New Mexico State University, Las Cruces, NM.
- Euler, Robert C. 1954. Environmental adaptation at Zia Pueblo. *Human Organization*. 12(4): 27–32.

- Fergusson, Harvey 1931. Rio Grande. Alfred A. Knopf, New York, NY.
- Findley, James S.; Harris, Arthur H.; Wilson, Don E.; Jones, Clyde. 1975. The mammals of New Mexico. University of New Mexico Press, Albuquerque, NM.
- Flores, Dan 1992. An introduction to the environmental history of northern New Mexico. In: D.C. Hayes et al. (eds.), A Southwestern mosaic: Proceedings of the Southwestern Region New Perspectives University Colloquium. Gen. Tech. Rep. RM-216. Fort Collins, CO: U.S Department of Agriculture, Rocky Mountain Forest and Range Experiment Station. 5-8 pp.
- Follansbee, Robert; Dean, H.J. 1915. Water resources of the Rio Grande Basin, 1888-1913. U.S. Geological Service Water-Supply Paper No. 358, Washington, D.C.
- Follett, W.W. 1898. A study of the use of water for irrigation in the Rio Grande del Norte. In: Senate Document No. 229, 55th Congress, 2nd Session, Washington, D.C. 47-177 pp.
- Ford, Richard I. 1972. An ecological perspective on the Eastern Pueblos. In: New perspectives on the Pueblos, edited by Alfonso Ortiz, University of New Mexico Press, Albuquerque, NM. 1-17 pp.
- Ford, Richard I. 1987. The new Pueblo economy. In: When cultures meet: Remembering San Gabriel del Yunge Oweenge. Sunstone Press, Santa Fe, NM. 73-87 pp.
- Forsling, C. 1950. The Rio Grande Valley in New Mexico - Its present and future. Journal of Forestry. 48(9): 439-441.
- Foxx, Teralene S. (compiler, editor) 1981. La Mesa Fire Symposium. Los Alamos, New Mexico October 6 & 7, 1981. Department of Energy, Los Alamos, NM.
- Frazer, Robert W. (editor and annotator) 1981. Over the Chihuahua and Santa Fe trails 1847-1848: George Rutledge Gibson's journal. University of New Mexico Press, Albuquerque, NM.
- Freehling, Michael D. 1982. Riparian woodlands of the middle Rio Grande Valley, New Mexico: A study of bird populations and vegetation with special reference to Russian-olive (*Elaeagnus angustifolia*). U.S. Fish and Wildlife Service, Albuquerque, NM.
- Fritts, Harold C. 1965. Tree ring evidence for climatic change in western North America, Monthly Weather Review 93(7): 421-443.
- Gabin, Vickie L.; Lesperance, Lee E. 1977. New Mexico climatological data: Precipitation, temperature, evaporation and wind: Monthly and annual mean, 1850-1975. W.K. Summers and Associates, Socorro, NM.
- Gallacher, Cathryn A. (compiler) 1986. Oral history collections in the Southwest region: A directory and subject guide. Southwest Oral History Association, University of California, Los Angeles, CA.
- Gilpin, Laura. 1949. The Rio Grande: River of destiny. Duell, Sloan, and Pearce, New York, NY.
- Gregg, Josiah 1966. Commerce of the prairies. 2 vols. Readex Microprint Corporation, n.p.
- Gross, Frederick A.; Dick-Peddie, William A. 1979. A map of primeval vegetation on New Mexico. Southwestern Naturalist. 24(1): 115-122.
- Hackett, Charles Wilson (editor) 1937. Historical documents relating to New Mexico, Nueva Vizcaya and approaches thereto, to 1773. Vol. 3. Carnegie Institution, Washington, D.C.
- Hammond, George P.; Rey, Agapito. 1940. Narratives of the Coronado Expedition. Coronado Cuarto-Centennial Publication, Vol. 2, UNM Press, Albuquerque, NM.
- Hammond, George P.; Rey, Agapito. 1966. The rediscovery of New Mexico 1580-1594: The explorations of Chamuscado, Espejo, Castano de Sosa, Morlete, and Leyva de Bonilla and Humana. University of New Mexico Press, Albuquerque, NM.
- Harper, Allan G.; Cordova, Andrew R.; Oberg, Kalervo. 1943. Man and resources in the Middle Rio Grande Valley. University of New Mexico Press, Albuquerque, NM.
- Harris, David R. 1966. Recent plant invasions in the arid and semi-arid Southwest of the United States. Annals, Association of American Geographers. 56(3): 408-422.
- Hay, John 1972. Salt Cedar and salinity on the upper Rio Grande. In: The Careless Technology edited by M. Farvar and J.P. Milton. Natural History Press, Garden City, NY. 288-300 pp.
- Henshaw, H.W. 1875. Report upon the ornithological collections made in portions of Nevada, Utah, California, Colorado, New Mexico, and Arizona during the years 1871, 1872, 1873, and 1874. In: U.S. Geographic Exploration and Survey west of the 100th meridian, vol. 5, Washington, D.C. 131-507 pp.
- Hernandez, John W. et al. 1971. A socio-ecological evaluation of the Sevilleta Land Grant. New Mexico Environmental Institute, Las Cruces, NM.
- Hewett, Edgar Lee; Henderson, Janias; Robbins, Wilfred William. 1913. The physiography of the Rio Grande Valley, New Mexico, in relation to Pueblo

- culture. Bureau of American Ethnology Bulletin 54, Smithsonian Institution, Washington, D.C.
- Hewett, Edgar L.; Dutton, Bertha P. (editors) 1945. The Pueblo Indian world: Studies on the natural history of the Rio Grande Valley in relation to Pueblo Indian culture. University of New Mexico and School of American Research, Albuquerque, NM.
- Hink, V.C.; Ohmart, R.D. 1984. Middle Rio Grande biological survey. U.S. Army Corps of Engineers, Albuquerque, NM.
- Hodge, Frederick Webb; Hammond, George P.; Rey, Agapito (editors) 1945. Fray Alonso de Benavides revised memorial of 1634. University of New Mexico Press, Albuquerque, NM.
- Hodges, Paul V. 1938. Report on irrigation and water supply for each pueblo in New Mexico in the Rio Grande Basin. Manuscript, United Pueblos Agency, Albuquerque, NM.
- Horgan, Paul 1954. Great river: The Rio Grande in North American history. 2 vols. Rinehart and Company, New York, NY.
- Hubbard, John P. 1978. Revised check-list of the birds of New Mexico. New Mexico Ornithological Society Publication No. 6, Albuquerque, NM.
- Humphrey, Robert R. 1953. The desert grassland, past and present. *Journal of Range Management*. 6(3): 159-164.
- Humphrey, Robert R. 1987. 90 years and 535 miles: Vegetation changes along the Mexican border. University of New Mexico Press, Albuquerque, NM.
- Jackson, Ronald Vern; Teeple, Gary Ronald. 1978. New Mexico 1850 census index. Accelerated Indexing Systems, Bountiful, UT.
- Jenkins, Myra Ellen. 1968. Calendar of the microfilm edition of the Spanish Archives of New Mexico, 1621-1821. State of New Mexico Records Center, Santa Fe, NM.
- Jenkins, Myra Ellen. 1969. Guide to the microfilm edition of the Mexican Archives of New Mexico, 1821-1846. State of New Mexico Records Center, Santa Fe, NM.
- Jenkins, Myra Ellen. 1970. Calendar of the Mexican Archives of New Mexico, 1821-1846. State of New Mexico Records Center, Santa Fe, NM.
- Jenkins, Myra Ellen; Simmons, Marc; Martinez, Shirley. 1967. Guide to the microfilm of the Spanish Archives of New Mexico, 1621-1821. State of New Mexico Records Center, Santa Fe, NM.
- Jones, Hester. 1932. Uses of wood by the Spanish colonists in New Mexico. *New Mexico Historical Review*. 7(3): 3-27.
- Jones, Oakah L. Jr. 1979. Los Paisanos: Spanish settlers on the northern frontier of New Spain. University of Oklahoma Press, Norman, OK.
- Kelley, J. Charles. 1952. Factors involved in the abandonment of certain peripheral Southwestern settlements. *American Anthropologist*. 54(3): 356-387.
- Kelley, Vincent C. 1969. Albuquerque: Its mountains, valley, water, and volcanoes. Scenic Trips to the Geologic Past No. 9, State Bureau of Mines and Mineral Resources, New Mexico Institute of Mining and Technology, Socorro, NM.
- Kelley, Wilfred D. 1955. Settlement of the Middle Rio Grande Valley. *Journal of Geography*. 54(8): 387-399.
- Kessell, John L.; Hendricks, Rick. 1992. By force of arms: The journals of don Diego de Vargas. University of New Mexico Press, Albuquerque, NM.
- Klett, Mark et al. 1984. Second view, the rephotographic project. University of New Mexico Press, Albuquerque, NM.
- Koster, William J. 1957. Guide to the fishes of New Mexico. University of New Mexico Press, Albuquerque, NM.
- Leopold, Luna B. 1951. Vegetation of Southwestern watersheds in the nineteenth century, *Geographical Review*. 41(2): 295-316.
- Ligon, J. Stokley. 1927. Wildlife of New Mexico: Its conservation and management. Being a report on the Game Survey of the State 1926 and 1927. New Mexico State Game Commission, Santa Fe, NM.
- Ligon, J. Stokley. 1961. New Mexico birds and where to find them. University of New Mexico Press, Albuquerque, NM.
- Linford, Dee. 1956. Water resources of New Mexico. Manuscript on file, New Mexico state Engineer's Office and Interstate Stream Commission, Santa Fe, NM.
- Linford, Dee. 1967. Floral and faunal conditions in the Middle Rio Grande Valley of New Mexico at the time of U.S. occupation. Manuscript on file, New Mexico State Engineer's Office, Santa Fe, NM.
- Linford, Dee. 1968. Life conditions in the Rio Grande valley in New Mexico below Cochiti as reflected in contemporary journals and chronicles from 1880 to the present. Manuscript on file, New Mexico State Engineer's Office, Santa Fe, NM.
- Lymbery, Gordon A.; Pieper, Rex D. 1983. Ecology of pinyon-juniper vegetation in the northern Sacramento Mountains. *Agricultural Experiment Station Bulletin* 689, New Mexico State University, Las Cruces.
- Maes, Ernest E.; Fisher, L.H. 1937. A report on the Cuba Valley. *Regional Bulletin* No. 36, Conserva-

- tion Economics Series No. 9, Soil Conservation Services, Region Eight, Albuquerque, NM.
- Manthey, G.T. 1977. A floristic analysis of the Sevilleta Wildlife Refuge and the Ladron Mountains. M.A. Thesis, University of New Mexico, Albuquerque, NM.
- Marchiando, Patricia 1977. Faunal resources in the Cochiti study area. In: Archeological investigations in Cochiti Reservoir, New Mexico, Volume 1: A survey of regional variability, edited by Jan V. Biella and Richard C. Chapman, pp. 68–78, Office of Contract Archeology, University of New Mexico, Albuquerque, NM.
- Marshall, Michael P.; Walt, Henry J. 1984. Rio Abajo: Prehistory and history of a Rio Grande Province. Historic Preservation Division, Santa Fe, NM.
- Matthew, W. D. 1897. A revision of the Puerco fauna. American Museum of Natural History Bulletin 9. 259–323 pp.
- Meyer, Michael C. 1984. Water in the Hispanic Southwest: A social and legal history, 1550–1850. University of Arizona Press, Tucson.
- Middle Rio Grande Conservancy District. 1928. Report of the Chief Engineer; Plan for flood control, drainage, and irrigation in the Middle Rio Grande Conservancy District. Manuscript on file, New Mexico State Engineer's Office, Santa Fe, NM.
- Minckley, W.L.; Rinne, John N. 1985. Large woody debris in hot-desert streams: An historical review. Desert Plants. 7 (3): 142–153.
- Moir, William H.; Osterhandt, Frank O.; Taylor Jr., James R.; Fraser, Joseph G. 1971. Sevilleta: A socio-ecological survey of the Sevilleta Land grant. New Mexico Environmental Institute, Las Cruces, NM.
- Moore, J. 1986. Zoology of the Pacific Railroad surveys. American Naturalist. 26: 333–341.
- National Archives and Records Service. 1973. Aerial photographs in the National Archives. Special List No. 25. General Services Administration, Washington, D.C.
- Nickerson, Thomas (editor) 1945. That their fields shall prosper and their flocks increase: Problems of the Rio Grande watershed: A symposium. New Mexico Quarterly Review 15: 117–140.
- Nostrand, Richard L. 1980. The Hispano homeland in 1900. Annals: Association American Geographers 70(3): 382–396.
- Nostrand, Richard L. 1992. The Hispano homeland. University of Oklahoma Press, Norman, OK.
- Oberg, Kalervo 1940. Cultural factors and land-use planning in Cuba Valley, New Mexico. Rural Sociology. 5: 438–448.
- O'Connor, Diane Vogt. 1989. Guide to photographic collections at the Smithsonian Institution, National Museum of American History. 2 vols. Smithsonian Institution Press, Washington, D.C.
- Olmstead, Virginia Langham 1981. Spanish and Mexican censuses of New Mexico: 1750 to 1830. New Mexico Genealogical Society, Albuquerque, NM.
- Olmstead, Virginia Langham (translator and compiler) 1975. Spanish and Mexican colonial censuses of New Mexico: 1790, 1823, 1845. New Mexico Genealogical Society, Albuquerque, NM.
- Pattie, James O. 1966. The personal narrative of James O. Pattie, of Kentucky. Readex Microprint Corporation, New Canaan, CT.
- Poore, Henry R. 1893. Condition of the Pueblos in New Mexico in 1890. In: Extra Census Bulletin: Moqui Pueblo Indians of Arizona and Pueblo Indians of New Mexico. Census Office, U.S. Department of Interior, Washington, D.C. 99–119 pp.
- Pynch, J.A. et al. 1911. Report no. 1: The natural resources survey of the Conservation and Natural Resources Commission of New Mexico. New Mexico Printing Co., Santa Fe, NM.
- Rex, Heather F. (editor) 1991. Sourcebook for New Mexico geographic information. New Mexico Geographic Information Council, Albuquerque, NM.
- Riley, Carroll L. 1987. The frontier people: The Greater Southwest in the protohistoric period. University of New Mexico Press, Albuquerque, NM.
- Robinson, T.W. 1958. Phreatophytes. Geological Survey Water-Supply Paper 1423. U.S. Geological Survey, Washington, D.C.
- Robinson, T.W. 1965. Introduction, spread and areal extent of salt-cedar (Tamarix) in the western states. Geological Survey Professional Paper 491-A. U.S. Geological Survey, Washington, D.C.
- Rogers, G.F. 1982. Then and now: A photographic history of vegetation change in the central Great Basin. University of Utah Press, Salt Lake City, UT.
- Rogers, G.F. 1984. Bibliography of repeat photography for evaluating landscape change. University of Utah Press, Salt Lake City, UT.
- Rothman, Hal K. 1989. Cultural and environmental change on the Pajarito Plateau. New Mexico Historical Review. 64(2): 185–211.
- Rothman, Hal K. 1992. On rims and ridges: The Los Alamos area since 1880. University of Nebraska Press, Lincoln, NE.
- Rowley, William D. 1985. U.S. Forest Service grazing and range lands: A history. Texas A and M University Press, College Station, TX.

- Sallach, B.K. 1986. Vegetation changes in New Mexico documented by repeat photography. New Mexico State University, Las Cruces, NM. M.A. thesis.
- Sargeant, Kathryn 1987. Coping with the river: Settlements in Albuquerque's north valley. In: *Secrets of a city: Papers on Albuquerque area archaeology in honor of Richard A. Bice*, Papers of the Archaeological Society of New Mexico No. 13, edited by Anne V. Poore and John Montgomery. Ancient City Press, Santa Fe, NM. 31–47 pp.
- Sargeant, Kathryn; Davis, Mary. 1986. Shining river, precious land: An oral history of Albuquerque's north valley. The Albuquerque Museum, Albuquerque, NM.
- Schroeder, Albert H. 1968. Shifting for survival in the Spanish Southwest. *New Mexico Historical Review* 43(4): 291–310.
- Schroeder, Albert H. 1972. Rio Grande ethnohistory. In: *New Perspectives on the Pueblos*, edited by Alfonso Ortiz, University of New Mexico Press, Albuquerque, NM. 41–70 pp.
- Schroeder, Albert H. 1979. Pueblos abandoned in historic times. In: *Handbook of North American Indians: Southwest Vol. 9*, edited by Alfonso Ortiz, Smithsonian Institution, Washington, D.C. 236–254 pp.
- Scurlock, Dan. 1988a. Environmental overview and the protohistoric, Spanish Colonial, Mexican, and early Territorial periods. In: *Trails, rails, and roads: The central New Mexico east-west transportation corridor regional overview, Vol 1. Historic Overview*, by Boyd C. Pratt et al., New Mexico Historic Preservation Division, Santa Fe, NM. 3–88 pp.
- Scurlock, Dan. 1988b. Some early observations of wildlife in the Rio Grande Valley. *Bosque Tracks* 3(1–2).
- Scurlock, Dan. 1988c. The Rio Grande bosque: Ever changing. *New Mexico Historical Review*. 63(2): 131–140.
- Scurlock, Dan. 1991. Chapter 2. Native American settlement and land use, 1500s–1846. In: *The Southwest New Mexico regional overview*, by Boyd C. Pratt and Dan Scurlock. Historic Preservation Division, Santa Fe, NM. 35–60 pp.
- Scurlock, Dan. 1993a. Pinyon-juniper in Southwest history: An overview of historical use of, impact on, and change through time. Manuscript prepared for the P-J ecotone study, NSF grant, Biology Department, University of New Mexico, Albuquerque, NM.
- Scurlock, Dan. 1993b. Overview of the environmental history of the Rio Abajo, from La Bajada to San Marcial, New Mexico. Manuscript prepared for the Biological Interagency Team, Middle Rio Grande Bosque Management Project, Albuquerque, NM.
- Scurlock, Dan. 1993c. El Camino Real: An environmental history. In: *Papers on the Camino Real*, Bureau of Land Management, Santa Fe, NM.
- Scurlock, Dan. 1994. Historic climatic events in New Mexico. Manuscript on file with the author, Wingswept Research, Albuquerque, NM.
- Simmons, Marc. 1972. Spanish irrigation practices in New Mexico. *New Mexico Historical Review* 47(2): 135–150.
- Simmons, Marc. 1974. Settlement patterns and village plans in colonial New Mexico. In: *The Spanish borderlands - A first reader*, edited by Oakah L. Jones Jr. Lorrian L. Morrison Publisher, Los Angeles, CA. 54–69 pp.
- Simmons, Marc. 1979a. History of Pueblo-Spanish relations to 1821. In: *Handbook of North American Indians: Southwest Vol. 9*. Edited by Alfonso Ortiz. Smithsonian Institution, Washington, D.C. 178–193 pp.
- Simmons, Marc. 1979b. History of the Pueblos since 1821. *Ibid.* 206–223 pp.
- Simmons, Marc. 1982. Albuquerque: A narrative history. University of New Mexico Press, Albuquerque, NM.
- Smith, E.R. 1953. History of grazing industry and range conservation in the Rio Grande Basin. *Journal of Range Management*. 6(6): 405–409.
- Snow, David H. 1976. Santiago to Guache: Notes for a tale of two (or more) Bernalillos. In: *Collected Papers in Honor of Marjorie Ferguson Lambert*, edited by Albert H. Schroeder, Albuquerque Archaeological Society Press, Albuquerque, NM. 54–69 pp.
- Sublette, J.E.; Hatch, M.D.; Sublette, Mary. 1990. The fishes of New Mexico. University of New Mexico Press, Albuquerque, NM.
- Sunseri, Alvin R. 1979. Seeds of discord: New Mexico in the aftermath of the American conquest, 1846–1861. Nelson-Hall, Chicago, IL.
- Swan, Susan Linda 1977. Climate, crops, and livestock: Some aspects of colonial Mexican agriculture. Ph.D. dissertation, Washington State University, Pullman, WA.
- Taft, Paul H. 1980. Albuquerque climate calendar, 1979–1980. American Bank of Commerce, Albuquerque, NM.
- Tainter, Joseph A.; Levine, Frances. 1987. Cultural resources overview: Central New Mexico. U.S. Department of Agriculture, Forest Service, Albuquerque, NM.

- querque and U.S. Department of Interior, Bureau of Land Management.
- Thomas, H.E. et al. 1963. Effects of drought in the Rio Grande Basin. U.S. Geological Survey Professional Paper 372-D, Washington, D.C.
- Thornton, Russell. 1987. American Indian holocaust and survival: A population history since 1492. University of Oklahoma Press, Norman, OK.
- Traylor, Diane et al. 1990. The 1977 La Mesa fire study: An investigation of fire and fire suppression impact on cultural resources in Bandelier National Monument. Southwest Cultural Resources Center Professional Papers Number 28, Division of Anthropology, National Park Service, Santa Fe, NM.
- Tuan, Yi-Fu; Everard, Cyril E.; Widdison, Jerold G.; Bennett, Iven. 1973. The Climate of New Mexico. New Mexico State Planning Office, Santa Fe, NM.
- Tucker, Edwin A. 1992. The early days: A sourcebook of Southwestern Region history, Book 3. U.S. Department of Agriculture, Forest Service Cultural Resources Management Report No. 12, Southwestern Region, Albuquerque, NM.
- Tyler, Daniel 1984. Sources for New Mexican history 1821–1848. Museum of New Mexico Press, Santa Fe, NM.
- U.S. Census Bureau. 1850–1900. Census of New Mexico: Population. Department of Commerce, Washington, D.C.
- Van Cleave, Marjorie. 1935. Vegetative changes in the Middle Rio Grande Conservancy District. University of New Mexico, Albuquerque, NM. M.A. thesis.
- Veblen, Thomas T.; Lorenz, Diane C. 1991. The Colorado front range: A century of ecological change. University of Utah Press, Salt Lake City, UT.
- Vivian, R. Gordon 1964. Excavations in a 17th century Jumano Pueblo, Gran Quivira. National Park Service Archeological Research Series 8, Washington, D.C.
- Warren, Edward Royal. 1942. The mammals of Colorado, 2nd ed. University of Oklahoma Press, Norman, OK.
- Watson, J.R. 1912. Plant geography of north-central New Mexico. Botanical Gazette. 54: 194–217.
- Weber, David J. 1971. The Taos trappers: The fur trade in the far Southwest, 1540–1846. University of Oklahoma Press, Norman, OK.
- Welsh, Michael 1985. The U.S. Army Corps of Engineers in the Middle Rio Grande Valley, 1935–1955. New Mexico Historical Review. 60(3): 295–316.
- Welsh, Michael E. 1987. U.S. Army Corps of Engineers: Albuquerque district, 1935–1985. University of New Mexico Press, Albuquerque, NM.
- Weniger, Del 1984. The explorers' Texas: The lands and waters. Eakin Press, Austin, TX.
- Westphall, Victor 1983. Mercedes reales: Hispanic land grants of the upper Rio Grande region. University of New Mexico Press, Albuquerque, NM.
- White, Leslie A. 1935. The Pueblo of Santo Domingo, New Mexico. Memoirs of the American Anthropological Association, No. 43, Menasha, WI.
- Wislizenus, Frederick A. 1969. Memoir of a tour to northern Mexico connected with Col. Doniphan's expedition in 1846 and 1847. Rio Grande Press, Glorieta, NM.
- Wooton, E.O. 1908. The range problem in New Mexico. NMC/Station Bulletin No. 66, Las Cruces, NM.
- Wortman, Richard A. 1971. Environmental implications of surface water resource development in the middle Rio Grande drainage, New Mexico. M.A. thesis, University of New Mexico, Albuquerque, NM.
- Wozniak, Frank E. 1987. Irrigation in the Rio Grande Valley, New Mexico: A study of the development of irrigation systems before 1945. Southwest Regional Office, Bureau of Reclamation, Amarillo, TX.
- Yeo, Herbert W. 1910. General description of the Rio Grande Valley from White Rock Canyon of the Rio Grande to old Fort Craig, New Mexico. Manuscript, U.S. Reclamation Service, El Paso, TX.
- Young, Gwen. 1980. Analysis of fauna remains. In: Tijeras Canyon: Analyses of the past, edited by Linda S. Cordell, pp. 88–120, University of New Mexico Press, Albuquerque, NM.
- Zaidliez, Edwin. 1979. Historical comparison photography: Missouri Breaks, Montana. Montana State Office, Bureau of Land Management, n.p.
- Zubrow, Ezra B. W. 1974. Population, contact, and climate in the New Mexican pueblos. Anthropological Papers of the University of Arizona No. 24, University of Arizona Press, Tucson, AZ.