



Chapter 2

Bosque Background

This chapter provides background information for you, the educator. We give a brief introduction to the Middle Rio Grande Valley and the ecology of its cottonwood bosque, and outline the changes that have led to its current ecological crisis. We also highlight some of the recent work to protect and restore the local floodplain ecosystems. This is followed by a brief explanation of some basic ecological concepts.

The Middle Rio Grande Bosque

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Bosque Background

Terms in bold are defined in the glossary.

The cottonwood forest that borders the Rio Grande in central New Mexico is a remnant of a unique and diminishing habitat. Known locally as the **bosque** (pronounced *boh-skay*), a Spanish word for “forest,” these **riparian**, or riverside, forests provide valuable resources for animals and plants living in the arid Southwest. Unfortunately, the Rio Grande and its bosque have been heavily altered by human activities, especially during the last century. Regulation of water flow in the river has not only impacted the organisms that live in the water, but has also changed the mosaic of vegetation types once present in the valley. Wetlands, once common in the floodplain, have been greatly reduced and the cottonwood forests are dying out. Non-native plants and animals have spread throughout the valley, often displacing the native species; without changes in current water-management practices, non-native trees and shrubs will soon dominate the bosque.

Fortunately, many citizens of the valley recognize the ecological, cultural and aesthetic values of the bosque and surrounding wetlands. Active restoration of native habitats is underway and local people are joining together to save the forests that remain. With our help, the bosque has a future. The first step to help the bosque is to learn its ways, to understand the complexity of this ecological system and to share this knowledge with others. This brief introduction provides you, the educator, with background information to support the activities that follow.

The Middle Rio Grande Valley

The state of New Mexico contains three distinct river systems: the Rio Grande, the Canadian River, which eventually drains into the Mississippi, and the San Juan and Gila rivers, which both drain into the Colorado. A fifth major river, the Pecos, drains into the Rio Grande in Texas and so is considered part of that system. Numerous smaller rivers and creeks all drain into one of these systems, or in a few cases into closed basins with no outflow. The Rio Grande is the dominant river system in New Mexico in terms of the area of its **watershed**, or the area of land from which water drains into the river (see *The Upper Watershed* section below for a more thorough explanation of watersheds).

In total, the Rio Grande stretches about 2,000 miles (3220 km) from its headwaters along the Continental Divide in the San Juan Mountains of southwestern Colorado to its outflow into the Gulf of Mexico near Brownsville, Texas, and Matamoros, Mexico. Along the way, the Rio Grande passes through three states in the United States (Colorado, New Mexico, Texas) and four in the Republic of Mexico (Chihuahua, Coahuila, Nuevo Leon, Tamaulipas). The Rio Grande, known as the Rio Bravo in Mexico, forms the international boundary between Texas and Mexico. In



this guide we focus on what is known locally as the Middle Rio Grande Valley. This name is a bit misleading, for it does not represent the actual “middle” of the river, but rather refers to the approximate middle of the portion of the river that passes through New Mexico. This is typically defined as extending from Cochiti Dam, north of Albuquerque, downstream 160 river miles (260 km) to San Marcial, New Mexico. The Middle Rio Grande represents approximately a third of the river’s length through New Mexico, but only 8% of the river’s total length. The Middle Rio Grande watershed in turn represents about 14% of the whole Rio Grande drainage basin, or 24,760 mi² (64,150 km²). The major tributaries along the Middle Rio Grande are (from north to south) Galisteo Creek, Jemez River, Rio Puerco and Rio Salado.



The Middle Rio Grande Valley includes four New Mexico counties (Sandoval, Bernalillo, Valencia and Socorro) and six Indian pueblos (Cochiti, Santo Domingo, San Felipe, Santa Ana, Sandia and Isleta). Other principal land and facility managers include the Middle Rio Grande Conservancy District, Bureau of Reclamation, Army Corps of Engineers, New Mexico Department of Game and Fish, U.S. Fish and Wildlife Service, New Mexico State Parks, the City of Albuquerque Parks and Recreation Division, and private landowners.

The dominant geographic feature in the Middle Rio Grande Valley is the Rio Grande Rift, which extends more than 500 miles (800 km) from central Colorado through New Mexico. A **rift** occurs when two sides of a fault zone pull away from each other, leaving a large, trench-like valley. The crust beneath the rift has been stretched and thinned by extensional fault movements. The valley is actually a series of basins, each slightly lower in elevation as you move south (thus to call it a single rift is not quite correct, as that implies a single trough, but it is typically referred to this way). Each of these basins once contained its own **ephemeral** (seasonal) lake. Over time water eroded the canyons between basins, eventually merging into the continuous river. The term “valley” is thus also not technically correct, because a valley is carved by a river that cuts through the bedrock rather than taking advantage of a trough that was already there, but this is another term that is accepted as correct and so will be used here. The Rio Grande Rift has been geologically active for about the last 20 million years while the Rio Grande itself has flowed in its current location through the valley for 1–2 million years. A more detailed geologic history is given in Chapter 5, Geologic History of the Rio Grande Valley.

The climate of the region has been arid to semi-arid over the past 5,000 years, although cyclical drought/wet-year patterns have occurred during this period. These cycles are influenced by the **El Niño/La Niña** phenomenon, which is caused by periods of variation in water temperatures and barometric pressures in the eastern Pacific Ocean. During El Niño years, New Mexico experiences higher than average winter precipitation, resulting in high spring flows in the Rio Grande, as well as in the Pecos and Gila rivers. In contrast, La Niña years result in drought conditions here in the valley and low water levels in the river.

Rio Grande Basin

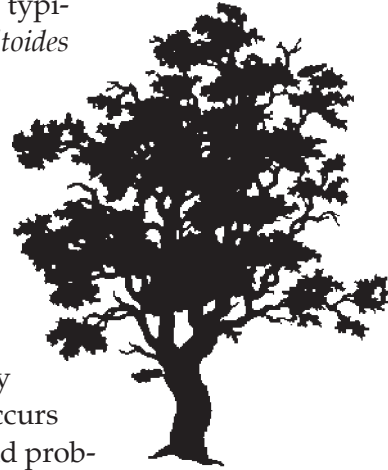


-  Basin
-  State Boundary
-  Closed Basin
-  Rivers



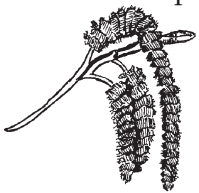
Rio Grande Cottonwoods

Riparian forests of the Middle Rio Grande Valley are typically composed of Rio Grande cottonwoods (*Populus deltoides* subsp. *wislizenii*), a subspecies of the plains (prairie) cottonwood (*Populus deltoides*). There has been some confusion in the scientific literature as to the specific identity of Rio Grande cottonwoods, but shoot, bud and capsule characters align this subspecies with the eastern *Populus deltoides* rather than with Fremont cottonwoods (*Populus fremontii*) as often stated. The center of the distribution of Rio Grande cottonwoods lies along the upper Rio Grande drainage, particularly through the Middle Rio Grande Valley. The species occurs along the Rio Grande from about El Paso northward and probably into the Colorado River drainage of northeastern Arizona, eastern Utah and western Colorado, though Fremont cottonwoods are present in the Colorado River drainage as well. Generally in New Mexico, cottonwoods west of the Rio Grande are Fremont cottonwoods (such as in the Gila and San Francisco watersheds) while those to the east are plains cottonwoods. However, there is considerable hybridization among cottonwoods, and there remains some question as to definite boundaries among species and subspecies. Fortunately, the ecology of these floodplain species is similar, so that knowing whether a tree belongs to *P. deltoides* or *P. fremontii* is relatively unimportant in the context of this guide.

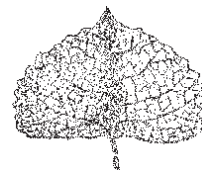


Cottonwoods grow well only where their roots can reach moisture provided by underground water and where their seeds can germinate on bare, moist soil. Thus, they are limited to areas with permanent water supplies. Although once widespread throughout low-elevation floodplains, many cottonwood forests have been cleared for farming, river-control projects and urban development. The only extensive tracts of Rio Grande cottonwoods remaining are found along the Rio Grande in central New Mexico, from approximately Española south to the Belen area. Unfortunately, these areas also face intensive impact by humans, severely threatening these unique and valuable habitats.

Rio Grande cottonwoods have thick and fissured gray bark and heart- or triangular-shaped leaves. They can reach approximately three feet (one meter) in diameter and 90 feet (30 meters) tall, but their size depends largely on water availability and so it is difficult to age a tree based on size alone. Male and female flowers occur on separate individuals, and small cottonwoods (whether young or just water-stressed) typically do not produce any flowers at all. In the spring, male trees bear flowers in long red clusters called **catkins**. The pollen produced by male flowers is carried by the wind to female flowers on adjacent trees, which are borne in long, greenish clusters. If pollinated, the female flowers develop into capsules containing tiny seeds with cottony plumes. Female trees can produce thousands of these tiny seeds, which are



male catkin



cottonwood leaf



easily dispersed long distances by wind or water. Seeds are produced during a brief period in late spring/early summer, which, prior to river regulation, corresponded to the peak of river flows when the river often flooded over its banks. To germinate, cottonwood seeds require scoured sand bars, which provide bare soil, moisture and plenty of sunlight. Many of the seeds land in unsuitable places, and will fail to develop. Those lucky enough to land on moist, open soil quickly develop roots, and if the post-flood soil moisture does not decrease too rapidly, the roots will soon reach down to the **capillary bed** above the **water table**. The water table is the upper surface of saturated ground water, while the capillary bed is a zone of soil above the saturated zone that consists of small spaces containing moisture held by capillary action. The ability of plants to use underground water is important in a region of irregular surface water, and cottonwoods cannot survive where the water table is too deep. Plants such as cottonwoods that can tap their roots directly into the ground water are called **phreatophytes**.

A Dynamic System

Prior to measurable human influence in the 14th century, the Rio Grande probably flowed year-round, as a meandering, sinuous, braided stream. That is, rather than being confined to a single channel as it is today, the location of the river moved within the floodplain. Most unregulated streams form a series of smooth, loop-like bends called **meanders**. These meanders occur in channels with low-gradient slopes because energy generated from flowing water spreads out as evenly as possible along its course. The location of the meander, and thus of the river, shifts when swift currents erode the outer bank of a meander bend and slow water deposits sediment on the inner side of the meander. Over time, the river will shift and move considerably in this way. Sometimes an entire loop is cut off from the rest of the river as the river tries to take the shortest route, forming an **oxbow**. This area remains wet, like a small pond or marsh, for some time and then slowly dries out, resulting in changing plant communities. The river was also once more braided than it is now. A **braided** river consists of two or more interconnected channels separated by sand bars or islands. An active river may flow in only a portion of the braided channels at a given time, but during a single season may shift and move across most or all of the channel system. Occasionally the location of the river channel shifts abruptly on the broad floodplain as major floods cut new channels and drop sediment to block off old ones.



meander

Because of the dynamic nature of the river, the Middle Rio Grande Valley would have continuously supported a patchwork of plant communities. Clearly all such communities, including the cottonwood forest, depend on the stream movement for their existence. Sand bars formed by the shifting river provide the conditions needed for cottonwood establishment. Seedlings that germinate on a newly scoured sand bar produce a cohort of plants of the same age, and if these survive future periods of high water, they will grow into a stand of young trees of about the same size. New seedlings cannot grow in a forest with a closed canopy, which prevents



adequate sunlight from reaching the floor, but as the river shifts its course, it may knock out a section of mature forest, thus providing the space needed for the establishment of new stands. The result is a variety of patches ranging from newly established seedlings to old, mature stands of huge trees to open areas with few trees. Such a patchwork of vegetation types is termed a **mosaic**. In addition to the more catastrophic effects of large floods, the bosque once benefited from the effects of annual inundation (the **flood pulse**) as the river overflowed its banks during the high spring runoff. Such low-intensity flooding provided water and nutrient-laden sediment to the forest. It also influenced a variety of processes, such as the rate at which nutrients cycle through the system, and limited the accumulation of leaf litter and woody debris on the forest floor.

Historically, these forest patches were interspersed with wetland areas. A **wetland** is a transitional zone between **terrestrial** (land) and **aquatic** (water) systems, where the water table is at or near the surface, or where land is covered by water at least part of the year. Wetlands in the Middle Rio Grande Valley included wet meadows, marshes, sloughs, ponds and small lakes. In combination, these wetland areas were probably a significant component of the floodplain ecosystem, greatly affecting the vegetation and animals present. They were formed partly by the meandering nature of the river and partly by the high water table in the valley; in some areas the water table was actually at the surface, supporting water-loving plants. The resulting mosaic of vegetation types, consisting of patches of cottonwood forest of different ages mixed with various wetland communities and open areas of low terrestrial vegetation, in turn supported a large diversity of organisms. As a consequence, the Middle Rio Grande Valley had an extremely rich assortment of plant and animal life.

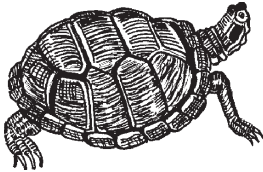


wetland vegetation

Plants and Animals of the Middle Rio Grande Valley

The river and its floodplain support a variety of plants and animals. In addition to the Rio Grande cottonwoods, native woody plants along the Middle Rio Grande include Goodding and peachleaf willows (*Salix gooddingii* and *Salix amygdaloides*), New Mexico olive (*Forestiera neomexicana*), coyote willow (*Salix exigua*), false indigo (*Amorpha fruticosa*), Anderson wolfberry (*Lycium andersonii*), seepwillow (*Baccharis glutinosa*) and others. Various species of grasses, forbs and aquatic plants were once present.

New Mexico, as a state, supports one of North America's most diversified faunas, resulting from its diversity of landforms, elevation, vegetation and climatic history. This was likely reflected in a wealth of animal species in the Middle Rio Grande Valley, although no documented descriptions exist of aquatic or terrestrial animals prior to the arrival of Europeans. Most of the terrestrial animal species that currently use the valley were present before the arrival of Coronado in 1540. Others, including the jaguar, gray wolf and grizzly, were occasional visitors to the riparian corridor.



red-eared slider

Throughout the arid Southwest, riparian areas support a greater number and variety of vertebrate species than surrounding uplands. Amphibians require aquatic habitats for at least part of their life cycles, thus conditions in the valley were once ideal for these animals. At least nine species of native amphibians, including many reptiles, use the bosque. The Middle Rio Grande Valley supports at least three turtle species, nine lizard species and 13 snake species. Early documentation of birds suggests a great variety of species present, as both permanent residents and seasonal visitors.

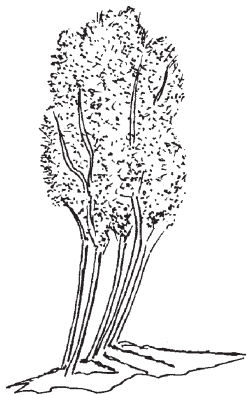
One recent study revealed over 270 species of birds in Rio Grande riparian habitats; 85 to 95 of these species were probably breeding in the valley. There are over 60 species of mammals in the bosque, most of which are rodents; 11 species of bats use the valley. In addition, although often overlooked and poorly studied, the terrestrial invertebrates (isopods, spiders, insects, etc.) of the Middle Rio Grande Valley far exceed the vertebrates in numbers of species and individuals. The river itself historically supported between 17 and 27 species of native fish, as well as a huge variety of aquatic invertebrates. Faunal and floral species lists are provided in Appendix F and G, respectively.

The Upper Watershed

The term **watershed** is often used when discussing river systems. The meaning of this term has changed somewhat from its original definition, particularly in the U.S. Originally, the term “watershed” referred to the boundary between catchments or drainage basins. That is, watershed referred to an area or ridge of land that separates waters flowing into different rivers, basins, or seas. Over the years, U.S. scientists used the term watershed interchangeably with “drainage basin,” so that now another accepted definition for watershed is an area or region drained by a river, river system, or other body of water; this is also the definition of drainage basin. We will use this latter definition, since this permeates the literature that teachers are likely to encounter. A watershed can be viewed at many different scales. A small arroyo has a watershed, which is the area that drains water into that arroyo, while this same area will also be part of a larger watershed that includes all the area that feeds the stream into which the arroyo drains, and likewise in a watershed for the larger river into which the stream drains. In this way, the watershed of a large river may contain thousands of smaller watersheds. It is important to remember that the watershed of a large river, such as the Rio Grande, extends far inland and up into the mountains. In fact, all land on Earth is part of some watershed, since water from any point of land eventually drains into a river system or a sea (or in some cases into a closed basin with no outflow). The watershed for the Rio Grande includes the three U.S. states that the river crosses (Colorado, New Mexico and Texas), while in Mexico, the watershed includes five states (Chihuahua, Coahuila, Nuevo Leon, Tamaulipas and Durango) even though the river only passes through four of these states (all but Durango). Thus people, as well as plants and non-human animals, over a vast area are connected by this common watershed that supports the Rio Grande. We do not have to live immediately next to the river to affect it—actions taken far inland can have significant impacts as well.



Most of our discussion in this guide focuses on the main stem of the Rio Grande in central New Mexico, which is a floodplain river. The upper reaches of the Rio Grande and its tributaries (all of which we will call “upper reaches” here for simplicity) differ in many ways from the Middle Rio Grande, both in the physical characteristics of the streams and in the species of plants and animals present. Because upper reaches each collect water from much smaller areas than the Middle Rio Grande, they contain much less water and thus are narrower. They tend naturally to be more contained within a narrow channel, and thus fairly straight, rather than meandering across a floodplain as does the lower river. Although smaller in size than floodplain rivers, these upper-reach streams tend to have faster flowing water, with alternating riffle (rapids) and pool sections. The streambed tends to include boulders and coarse cobble, rather than the finer gravel, sand or clay substrates seen in larger rivers. The water is generally cold and with few suspended sediments, thus providing a home for coldwater fish including various species of trout, as well as insects such as caddisfly larvae. Typically the riparian vegetation along an upper reach stream forms a very narrow band, including species such as narrowleaf cottonwood (*Populus angustifolia*), black willow (*Salix scouleriana*), thinleaf alder (*Alnus tenuifolia*), boxelder (*Acer negundo*) and red-osier dogwood (*Cornus stolonifera*). Although there is considerable overlap among birds that use lowland and upper-reach riparian areas, some, such as the American dipper, are unique to these fast water systems. The proximity of these streams to mountain habitats means that some different species of mammals, such as elk and black bear, are typical here.



thinleaf alder

Human Use of the River and Bosque

Humans first arrived in what is now known as the Middle Rio Grande Valley 11,000 to 15,000 years ago, toward the end of the last ice age. Early inhabitants were hunters and gatherers, first hunting the now-extinct large mammals such as mammoths, tapirs and sloths and then modern animals. These early people moved up and down the valley and across the surrounding grasslands and foothills in search of food and other resources. Their low population densities and nomadic nature had minimal impact on the bosque. After agriculture was introduced to the valley around AD 400, people became sedentary and villages increased in size. Settlements concentrated along the river, which provided adequate water for their crops. These first farmers were the Ancestral Puebloans (formerly called Anasazi), whose descendants the Spanish later named the Pueblo Indians. The Ancestral Puebloans practiced floodwater farming, utilizing natural overbank flooding to irrigate drought-tolerant crops, rather than installing diversion structures. Hunting and gathering were still important to their subsistence, and impacts on the river and its bosque were minimal. An era of great population increase and development began in the Middle Rio Grande Valley around AD 1350.



The first Europeans, led by Don Francisco Vasquez de Coronado, entered the middle valley in 1540. At that time, an estimated 25,000 acres (10,000 ha) of land were being farmed. Cornfields intermingled with patches of cottonwood trees and 12 pueblos were established near present-day Albuquerque. Human influence on the Middle Rio Grande Valley increased considerably following the Spanish colonization, beginning in 1598. The Spanish introduced irrigation agriculture to the Pueblo Indians, which allowed the import of crops such as wheat and lettuce. During this period, more extensive riparian areas were cleared and water was diverted for agriculture, and canals and **acequias** (irrigation ditches) were developed to bring water to the fields. By 1700, over 70,000 acres (28,000 ha) of land were being irrigated, and this increased to over 100,000 acres (40,000 ha) by 1800. By about 1850, valley communities were generally established in their present locations. The late 1800s saw an influx of Anglo-Americans into the Rio Grande Basin, with increasing conversion of land to agriculture; a peak of about 125,000 acres (50,000 ha) irrigated for crops was reached in the middle valley in about 1880. A more detailed discussion of acequias and early agriculture in the region is given in “Acequia Culture” in Chapter 5 and in Appendix D: Human Chronology.

The rapid settlement of the Rio Grande Valley from the early 1800s to the present resulted in significant impacts on the aquatic and riparian ecosystems. Sediments eroded from adjacent upland areas as a result of overgrazing and deforestation were deposited in the river, causing riverbed **aggradation** (a rising riverbed relative to the surrounding floodplain). That, in turn, raised floodplain water table levels. The result was waterlogged soils of high salinity, which negatively affected cultivation; by 1926 only about 45,000 acres (18,200 ha) were being irrigated. Other human impacts during this period included the direct removal of native floodplain forests, hunting and trapping, grazing and pollution.

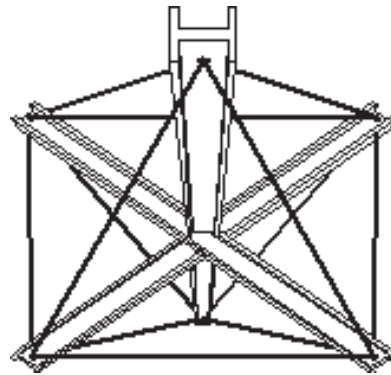
Water-management facilities were increasingly constructed along the Rio Grande in the late 1800s and early 1900s. Several water-supply dams and reservoirs had been built in the Colorado headwaters of the Rio Grande by 1913, and Elephant Butte Dam, at the lower end of the Middle Rio Grande Valley, was completed in 1916. In 1925, the Middle Rio Grande Conservancy District (MRGCD) was authorized by the New Mexico state legislature to alleviate concerns over the decrease in irrigated land resulting from water shortages, poor drainage, inadequate irrigation facilities and periodic flooding. The MRGCD was designated to provide the middle valley with a complete and efficient irrigation system as well as drainage and flood-control facilities. This resulted in the construction of El Vado Dam on the Rio Chama, six diversion dams or headings in the middle valley, 345 miles (555 km) of drainage canals, 181 miles (290 km) of river levees, 250 miles (400 km) of main irrigation ditches, and rehabilitation of nearly 400 miles (640 km) of old irrigation ditches. Construction was completed in 1936. These changes greatly reduced the waterlogging of valley soils and improved the distribution of irrigation water, allowing the productive agricultural business present in the valley today. However, a flood that breached and overtopped the levees in 1941 led to the belief that more extensive flood control was needed. To reduce the danger of future flooding, four dams (Abiquiu, Jemez Canyon, Galisteo and Cochiti) were constructed. Cochiti



Dam was the last of these completed (in 1975) and its operation directly affects water levels along the middle valley. In addition to flood control, these dams were mandated for sediment retention, wildlife enhancement and recreation. Other changes included clearing the floodway, straightening the river channel, installing **jetty jacks** to stabilize the channel and protect levees and enlarging and adding to the levees. In 2000, about 73,000 acres (29,200 ha) were being irrigated along the Middle Rio Grande Valley.

Jetty Jacks

“They keep the people out!” “They keep the animals in!” “They are for climbing!” . . . if you ask kids what the big metal structures in the bosque are, you will get all sorts of creative answers, and always a lot of interest. **Actually, they are designed to help stabilize the river channel and protect the levees.** The official name for one of these structures is a Kellner jetty, or jack (also often called “jetty jacks”). Made of steel angles and heavy wires, individual jacks are connected by wire ropes into lines. Installation of jacks began in 1951 by the U.S. Bureau of Reclamation and the U.S. Army Corps of Engineers, with two main objectives. First, jack lines help to stabilize the bank of the river. The jacks slow the water velocities and so encourage sediment to drop out of the river. The sediment builds up, and eventually riparian vegetation becomes established. This stabilizes the riverbank, preventing the river from meandering across the floodplain. Second, acting in a similar manner, jack lines that abut the levees are designed to protect the levee system, particularly from large floods that could erode the earthen levees. Now that the river has been stabilized, the jacks that define the channel are no longer needed, and in some areas such as Santa Ana Pueblo, Sandia Pueblo, and Los Lunas, jacks are being removed. However, this is a very costly process and cannot be undertaken along the whole Middle Rio Grande Valley. Although some jacks were removed in Albuquerque’s South Valley in summer 2002, most jacks along the valley, even though many are no longer necessary, will likely remain a part of the floodplain landscape into the future.



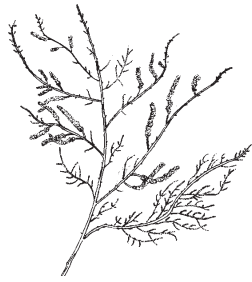


The use of Rio Grande water is heavily governed by state, interstate, federal and international laws, agreements and regulations. The Treaty of 1906 between the United States and Mexico provides a minimum water delivery to Mexico, while the Rio Grande Compact, signed in 1938, allocates water among the states of Colorado, New Mexico and Texas. All activities affecting water consumption must comply with these complex laws and regulations.

All municipal water systems along the middle valley currently use water from the underground aquifer for domestic and industrial uses, while river water is used for irrigation. Overall, in the U.S. and Mexico, about 80% of the water taken from the river is used for irrigation. Rates of ground water pumping by larger systems (primarily Albuquerque and Rio Rancho) now exceed the river's capacity to recharge the aquifer, so that the water table beneath Albuquerque has been greatly lowered. To accommodate its high demand for water, the City of Albuquerque plans to begin taking water for domestic uses directly from the Rio Grande by 2005. The City is legally entitled to a certain amount of river water from the San Juan–Chama Project. Completed in 1971, the project uses diversion dams, conveyance channels and tunnels to transport water from the San Juan River Basin (part of the Colorado River Basin) to the Rio Grande Basin, where it is dumped into Heron Reservoir on the Rio Chama. The City is one of several entities that contracted with the U.S. Department of Interior for this water, which is not subject to restrictions of the Rio Grande Compact. Currently, the water helps boost minimum flows in the Rio Grande. The impact that removing this water will have on the river and bosque ecosystems remains to be determined.

Biological Changes

The extensive hydrological (water) changes occurring in the Middle Rio Grande Valley during the last century have severely impacted its biological communities. Many wetlands dried up with the installation of drainage ditches, which rapidly lowered the water table. Overall, the Middle Rio Grande Valley lost over half of its wetlands between 1935 and 1989. Several rare plant species, found only in wetland areas, are severely threatened with loss of appropriate habitats. Although draining the valley initially benefited the reestablishment of the cottonwood bosque (which had been greatly reduced by heavy human use and waterlogged soils), the distribution of the forest is now largely limited to the area between the levees rather than throughout the wider floodplain. Further, the patchy mosaic of different habitat types has been lost and replaced with a more continuous, mature bosque within the new, narrow floodplain. This, combined with decreased overbank flooding, means that wildfires, which were probably not an important part of the bosque ecosystem historically, can now spread quickly along this continuous, dry corridor. The decrease in flooding has also led to an accumulation of leaf litter and woody debris within the forest, which provide fuels for the more catastrophic-level fires. In addition, manipulation of river flows and confinement of the river to a straightened and narrowed channel has decreased further cottonwood establishment, or limited it to areas within the active river channel. Now, as patches of the forest are cleared or die naturally, they are not replaced as rapidly as they are lost.



saltcedar

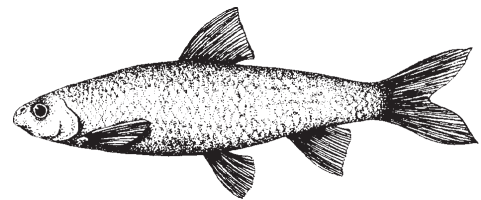
The introduction of non-native plants and animals has also had a significant impact on the native communities. Two species of introduced plants, saltcedar or tamarisk (*Tamarix chinensis*) and Russian olive (*Elaeagnus angustifolia*), have spread throughout the valley, due in large part to certain aspects of their biology. For example, saltcedar can produce seeds as early as its first year, and seeds are typically produced from early spring to late fall. This allows saltcedar to become established over a much broader window of time than cottonwoods and to take advantage of later summer thunderstorms and flooding. Unlike cottonwoods or saltcedar, Russian olive is shade tolerant and so can spread within the established forest. Both of these exotics can form dense thickets that stabilize the riverbank and decrease the likelihood of flooding, further contributing to the decline of cottonwoods. A number of other exotics, such as Siberian elm (*Ulmus pumila*), white mulberry (*Morus alba*), tree of heaven (*Ailanthus altissima*), sweet clover (*Melilotus alba*) and Johnson grass (*Sorghum halapense*), are now common in the bosque. In many places along the Middle Rio Grande Valley, these exotic plants now dominate the riverside forest. Predictions are that if water management continues as it has in the past, introduced plants will soon dominate the Valley bosque.

Notes on Names

Is that a northern flicker or a red-shafted flicker? A juniper titmouse or a plain titmouse? A Fremont or plains cottonwood? Species definitions and scientific names are never set in stone, which can lead to some confusion when reading the scientific literature, or simply learning the names of plants and animals. Sometimes, when scientists learn more detailed information about organisms, they may decide that what were once considered two separate species are really just one (as in the flicker woodpeckers) or what was thought to be just one species is really two (as in titmice, small birds related to chickadees). Or, there just may be confusion about which species a population is most closely aligned with, particularly among species that can hybridize (as with Rio Grande cottonwoods). When species designations change, so do the scientific names. Unfortunately, such changes may occur several times, making it difficult to keep track of which name is correct. For example, there has been considerable inconsistency in the scientific literature as to the proper scientific name for the species of saltcedar (tamarisk) that occurs along the Middle Rio Grande Valley. This species has been referred to as *Tamarix chinensis*, *Tamarix pentandra*, and, most common in recent literature, *Tamarix ramosissima*. It now appears that *T. chinensis* and *T. ramosissima* are in fact the same species, and by the rules of scientific nomenclature, the name *Tamarix chinensis* is used because it was given first. So, although the name for saltcedar was changed to *Tamarix ramosissima* in the supplemental pages sent out with the previous edition of this guide, we now revert back to the name *T. chinensis*.



Between 36% and 73% of the native fish species have been completely eliminated from the Middle Rio Grande, while over 20 non-native species have been introduced. Non-native fish will likely continue to increase as long as the natural hydrological cycle of the river is disrupted. Considerable focus has been placed recently on the decline of the Rio Grande silvery minnow. This minnow was once abundant and widespread, occurring along the Rio Grande from approximately Espanola to the Gulf of Mexico as well as along the Pecos River. It is now restricted to about 5 % of its former historic range, occurring only along part of the Middle Rio Grande. Although several factors have led to the decline of silvery minnows, most significant has been the alteration of their habitat by river channelization, water diversion and impoundment. Silvery minnows spawn in response to the increase in stream flow resulting from the spring runoff or summer thunderstorms, and their eggs drift in the water. Eggs and larvae are typically carried downstream, and the presence of diversion dams along the river now prevents adults from returning upstream. This means that the minnows tend to be concentrated along the lowermost portion of their current range, south of the San Acacia Diversion Dam. This portion of the river often goes dry during the summer when water is diverted for agricultural use, thus leaving the minnows without suitable habitat. Although the river may have periodically dried up prior to river regulation, the combination of the presence of diversions dams, which prevent upstream movement by adult minnows, and the rapid removal of water for irrigation, now typically traps minnows in the dewatered zones. Even when complete desiccation is avoided, minnows are concentrated into small pools where they suffer high predation rates from native and exotic fish, birds and mammals, and where the outbreak of pathogenic diseases is high. The struggle over the survival of silvery minnows represents more than just the survival of this one species, as the hydrological conditions required by minnows benefit a variety of other riverine and riparian organisms.



Rio Grande silvery minnow

Native amphibians, particularly leopard frogs and chorus frogs, are declining with the loss of wetlands and predation by, and competition with, non-native bullfrogs. Bosque songbird populations face many threats; for example, species such as the southwest willow flycatcher are rapidly losing appropriate breeding habitat and many species of warblers and vireos suffer heavily from nest parasitism by brown-headed cowbirds. The Rio Grande turkey was eliminated from the valley due to hunting, while sandhill crane populations were significantly reduced. Fortunately, reintroduction programs for these species appear to be successful. Rodents such as the meadow jumping mouse and tawny-bellied cotton rat, which favor wet meadows, have declined with the loss of these habitats. Beaver were largely eliminated near the end of the 19th century, mainly due to trapping and habitat depletion, but have been reintroduced and have largely recovered. The jaguar, wolf, grizzly bear and mink have disappeared from the valley. Livestock, including cattle, sheep, goats, horses, donkeys and mules, heavily impact the riparian trees, shrubs, grasses and forbs, while feral cats and dogs negatively affect native animal populations. The

invertebrate communities have changed as well; introduced crustacean isopods (pillbugs and woodlice) are now the most abundant macrodetritivores (invertebrates that chew on fallen organic material) on the forest floor.



The Bosque Needs Our Help: Research and Restoration

We are fortunate to have such a rich and diverse ecosystem here in our region, but the threats to the bosque are great and ever-increasing. Indeed, time is running short for its preservation. Although we will never be able to restore the valley to its natural condition, if we reduce our impact now we may be able to preserve some of its functional integrity. Our past and current modifications have severely altered the Middle Rio Grande bosque, thus requiring active management for future persistence of this ecosystem. Fortunately, restoration efforts are underway and various agencies governing land along the river are beginning to work together to develop strategies for conservation.

Rio Lingo: a Sidebar on Spanish River Words

Modeling good pronunciation and use of Spanish river words for students is beneficial to all in our diverse cultural environment. Except for the rolling r's, which take some practice, all the sounds of Spanish are already in English. It is a matter of transferring the right ones.

acequia [ahsehkeeah] traditional irrigation canals that expand the riparian zone. This word is borrowed from Arabic.

agua [ahwah] the water of life

alamo [ahlahmo] cottonwood; alameda is a grove of cottonwoods.

ancón [ahnkohn] oxbow, a meander in the river

bosque [bowskeh] forest. Use "long o" as in "bow and arrow." Otherwise you are actually saying the word "bosky" from old English, an adjective meaning wooded. The Scottish poet Robert Burns once wrote a poem titled "The Bosky Bourne" (the wooded creek).

ciénega [seaenega] marsh or wetland

jara [hahdda] willow, the brushy kind, like coyote or black willows. The single "r" in Spanish is like the English "tt" or "dd" in "butter or ladder." Willow trees with big trunks are "sauces" [sowseh].

presa [prehsah] dam, big and small

remanso [rehmahns] side channel, backwater, quiet water.

río [reeoh] Remember río means river, so Río Grande River is an overload.



The conservation and restoration of ecosystems begins with ecological knowledge of the system in question. After the flow of the Rio Grande had been regulated and the shape of the river channel had been altered for many years, scientists began to recognize problems within the bosque ecosystem. Research designed to help scientists better understand the system began in 1986 when two University of New Mexico professors (Drs. Clifford Crawford and Manuel Molles) began a course called Bosque Biology. This course, which is still taught today, takes graduate and undergraduate students into the bosque to collect data on a variety of population and ecosystem components, such as litterfall, arthropod activity and ground water levels. This research raised questions about the effects of eliminating flooding from the riparian ecosystem and led these scientists to begin an experimental study of the effects of flooding on the Rio Grande bosque. Begun in 1991 at the Bosque del Apache National Wildlife Refuge near Socorro, this research included three artificially created floods designed to mimic the historic flood pulse. A variety of ecological parameters were monitored before and after flooding. The results of the study indicated many benefits to flooding in this system and highlighted the need to restore flooding to riparian forests along the valley.

Efforts to conserve and restore the Rio Grande bosque began in earnest in the early 1990s, when Senator Pete Domenici appointed nine citizens to the Rio Grande Bosque Conservation Committee with the task of examining the problems facing the bosque and making recommendations for its long-term protection. After nearly two years and with considerable public input, the Committee provided a series of recommendations addressing such issues as the institutional structure for management of the Middle Rio Grande, fire prevention and public education. One recommendation was to develop a biological management plan for the Middle Rio Grande. From this direction, the Bosque Biological Management Plan was produced in 1993 by an interagency team of scientists (see Crawford et al. 1993). In addition to summarizing a vast amount of information including the physical setting, aquatic and terrestrial ecology, hydrology and human history of the Middle Rio Grande bosque, the Management Plan provided 21 specific recommendations for preserving and restoring the Rio Grande floodplain ecosystems.

Armed with information from research projects such as the experimental flooding study, and with specific goals from the Bosque Biological Management Plan recommendations, resource managers working along the Middle Rio Grande have begun making changes. Agencies whose previous management practices had contributed to problems faced by the Rio Grande and its bosque are beginning to implement the new management procedures. Numerous restoration projects have been started along the Middle Rio Grande by municipal, state and federal agencies, pueblos, educational institutions and private organizations to remove non-native vegetation, replace native vegetation, reduce accumulations of fuel in the forest, alter streambed morphology (shape) and restore natural flooding. Three examples are briefly highlighted here.



The Pueblo of Santa Ana, located north of Bernalillo, is working towards removing non-native vegetation from approximately 1,000 acres (400 ha) of the historic floodplain of the Rio Grande and restoring aquatic habitat within the six-mile (9.6-km) reach that flows through the reservation. Revegetation efforts within the floodplain focus on restoring a mosaic of habitat types, including cottonwood pole planting, riparian shrub swales, bankline stabilization with coyote willow and salt-tolerant grasses and shrubs in upland areas. The river restoration efforts concentrate on halting channel degradation and incision (downcutting) through construction of “gradient restoration facilities” (GRFs). The GRFs prevent continued channel bed erosion, slow the flow velocities and promote sediment deposition. In addition to building GRFs, the Pueblo is lowering approximately 200 acres (80 ha) of river bars to increase available habitat for the Rio Grande silvery minnow and to promote over-bank flooding and sustainable riparian vegetation recruitment.

The Albuquerque Overbank Project (AOP) is a collaborative effort with participants from the U.S. Bureau of Reclamation, the University of New Mexico’s Department of Biology, the City of Albuquerque Open Space Division, the Middle Rio Grande Conservancy District, the New Mexico Natural Heritage Program, the U.S. Fish and Wildlife Service, the State of New Mexico Environment Department and the U.S. Army Corps of Engineers. Begun in 1998, the project involved clearing a dense, four-acre (1.6-ha) stand of non-native Russian olive from an attached sand bar (one joined to the bank of the river), and then lowering part of the cleared area by about two feet (0.6 m) to promote flooding by the river. Channels were constructed on the newly cleared area to enhance flooding and thereby promote cottonwood and willow establishment. Many parameters have been monitored at the site, including ground water levels, soil salinity, herbaceous and woody plant diversity and growth, and terrestrial arthropod, bird and beaver activity. In addition to testing methods for this type of restoration project, the AOP has provided a considerable amount of scientific information that will contribute to further such endeavors. Similar projects have already begun.

Along with providing a well-known winter home for large flocks of geese, cranes and ducks, the Bosque del Apache National Wildlife Refuge has been protecting and actively restoring native riparian forests for many years. The Refuge has been a leader in testing methods of exotic vegetation removal, with large tracts of non-native plants, especially saltcedar, cleared using various methods. Refuge personnel have also experimented with different revegetation techniques; large stands of native cottonwood forest now replace areas formerly overrun by saltcedar.

In addition to the many restoration projects now underway, scientific research continues to answer questions about the ecology of Rio Grande floodplain ecosystems, with a number of projects addressing a variety of topics. For example, the role of flooding is being studied further at a number of sites along the valley, as are rates of water use by native and non-native vegetation and by flooded and non-flooded forests. Other researchers are investigating the effects on wildlife of removing much of the excess fuels from the forest and on the recovery of riparian vegetation after wildfires. One exciting project that involves school groups is



the Bosque Ecosystem Monitoring Program (BEMP), which enables students to participate actively in scientific research. Funding for much of the research, restoration and education (including this *Bosque Education Guide*) taking place in the Middle Rio Grande Valley over the last decade has come from the “Bosque Initiative,” a special congressional appropriation administered through the U.S. Fish and Wildlife Service.

A Final Note

Survival of the bosque also requires an active effort by the citizens of the valley. This means we must educate ourselves and others as to the complexity and importance of this unique ecosystem and understand how our daily habits can affect it. It means making the needed changes in our lives to reduce our impact and produce positive effects. Most importantly, it means gaining a greater sense of connection with the bosque such that we will be willing to work for its survival. While much of the media focus on preservation of tropical rainforests highlights a vital and important task, we must not forget the destruction that takes place in our own backyards. We hope that through the use of this guide, you and your students will come to appreciate the unique value of the bosque, treasure it as a special place and understand the ecology of the system and how we all fit in. Finally, we hope you and your students will be inspired to help protect the bosque, as educators to tell family and friends about its unique qualities, and as advocates to try to make changes for its protection.

This essay benefitted from information supplied by Todd Caplan, Cliff Crawford, Cliff Dahm, Sterling Grogan, Esteban Muldavin and Nancy Umbreit.

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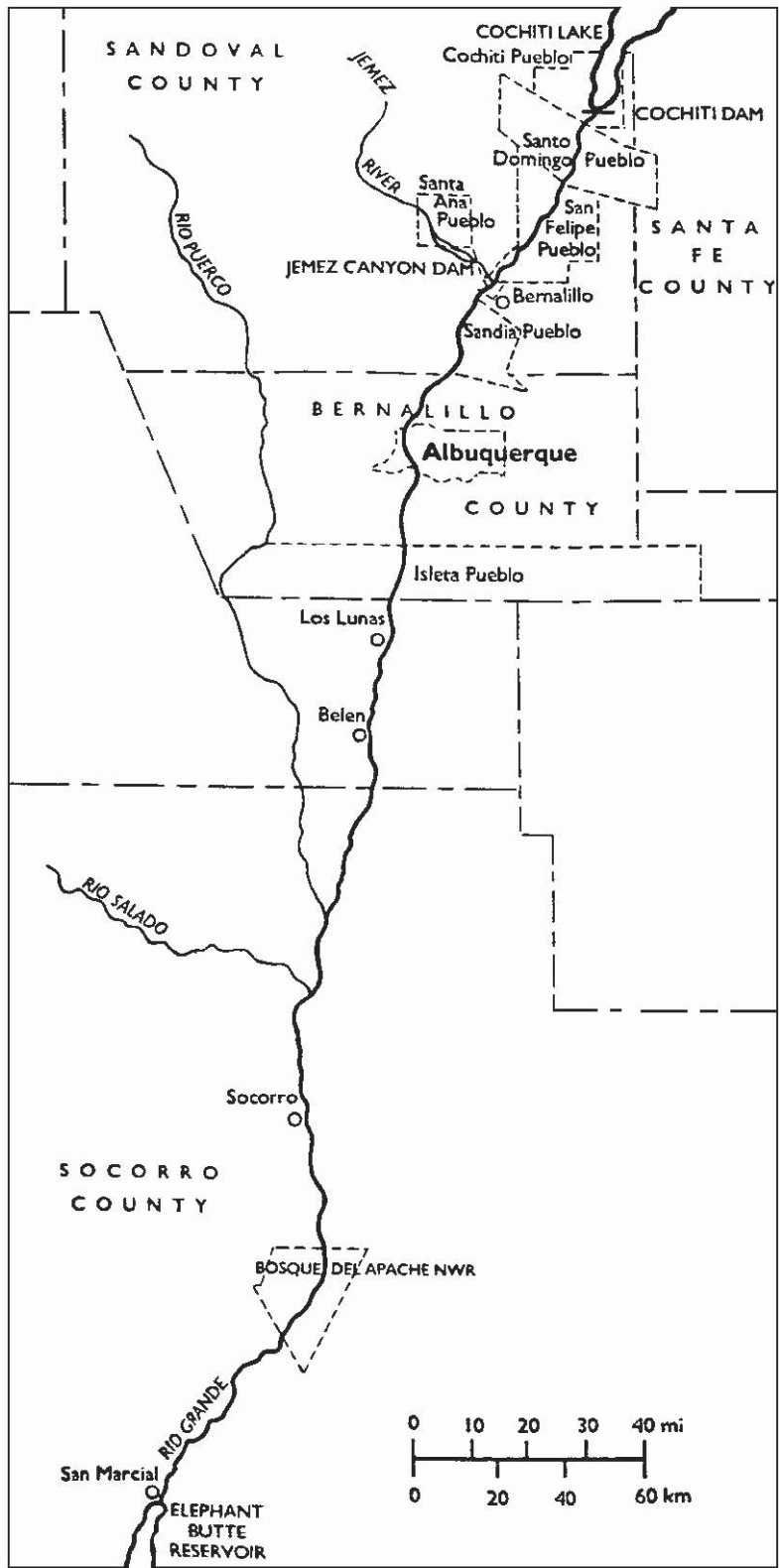
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The Middle Rio Grande Valley

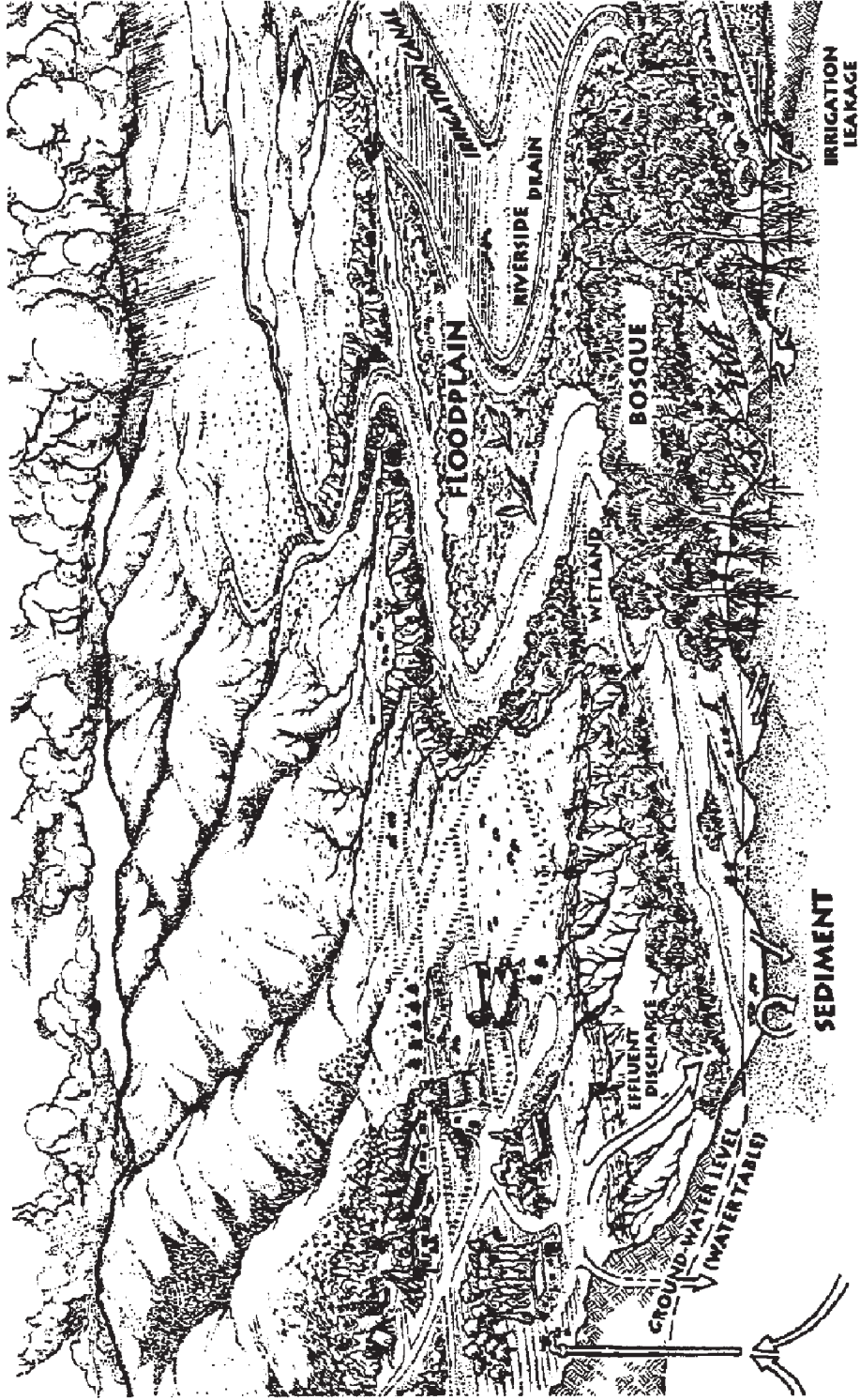


From *Middle Rio Grande Ecosystem: Bosque Biological Management Plan*. 1993.



Idealized Picture of the Middle Rio Grande Valley as an Ecosystem

drawing by William J. Underwood from *Middle Rio Grande Ecosystem: Bosque Biological Management Plan*



Basic Ecological Concepts

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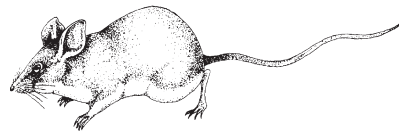


Biology, the study of life on Earth, is a multi-faceted academic field. Even the relatively young branch of biology known as ecology is complex, with many areas of specialization. It is impossible to provide a thorough explanation of these disciplines here, but the following essay includes some key concepts that will help you in your study of the Rio Grande bosque.

Levels of Taxonomic Classification

Taxonomy is the science of classification of organisms. Biologists classify organisms based on their evolutionary relationships, using a hierarchical system of grouping by shared features.

The fundamental unit of life on Earth is what biologists refer to as the **species**. Although the concept of a natural unit for classification is critical to many fields within the biological sciences, biologists are far from agreeing on its exact definition, and the meaning of a species may vary somewhat depending on the type of biologist you question. For our purposes, the widely accepted “biological species concept” is quite appropriate. The biological species concept states that a species is a population or series of populations whose members are able to interbreed freely under natural conditions and who do not breed with other species. Although there are exceptions to and difficulties with this definition, it works for most organisms. A simpler way to define species, which is not complete but will work for young audiences, is that a species is a unit of classification that refers to a population (group) or series of populations (groups) of closely related and similar organisms.



white-footed mouse

Closely related species are combined into a genus, while closely related genera form a family, and so on up the classification hierarchy. This classification hierarchy, listed from the largest or most inclusive category, is shown below. Taxa for the white-footed mouse are listed in the right-hand column as an example. Note that the genus and species names are always either italicized or underlined, with the genus name capitalized and the species name given in lower case.

Kingdom	Animalia
Phylum (animals) or Division (plants)	Chordata
subphylum	Vertebrata
Class.....	Mammalia
Order	Rodentia
Family.....	Muridae
Genus.....	<i>Peromyscus</i>
Species	<i>leucopus</i>



Levels of Ecological Classification

Ecology is the study of the relationships between organisms and the environment. Ecologists use a number of levels of classification that reflect ecological relationships. These terms have specific meanings in ecology. As in taxonomic classification, the fundamental unit of ecological classification is the species. For example, the most common species of mammal within the bosque is the white-footed mouse, whose scientific name, which is unique to this species, is *Peromyscus leucopus*. A **population** is a group of organisms of the same species that live in the same area at the same time. Thus we can talk about a population of white-footed mice living within a particular forest. A **community** is an association of organisms (plants, animals, microorganisms) that live in a particular place or habitat. These organisms affect each other in various ways, such as through a food chain or web (see below). For example, coyotes may eat white-footed mice; this predator–prey relationship is part of the community dynamics.

An **ecosystem** includes all the living organisms, the non-living components, a source of energy and the interactions among these in a given area. One difficulty in defining an ecosystem is in choosing the area you wish to discuss. An ecosystem can be as small as a drop of water or as big as the planet, the global ecosystem. Thus the term “ecosystem” sometimes seems a bit vague, or may seem like a catchall to include a wide variety of concepts. Throughout this guide, we will refer to the “riparian ecosystem.” By this we mean the living organisms (bacteria, fungi, plants, animals) that are found along the river, specifically the Rio Grande, and the interactions that occur among them and with the various non-living components, such as soil, as well as processes such as the hydrology and chemical reactions in the system and the input of sunlight energy.

A **landscape** is an area of land containing a patchwork of ecosystems. We can take a landscape perspective to look at the Middle Rio Grande Valley, which would include several ecosystems such as the riparian forest, wetlands (marshes, wet meadows), grasslands and agricultural fields.

Some Basic Ecological Concepts

The term **habitat** refers to the kind of place where an organism normally lives. It includes the arrangement of food, water, shelter and space that is suitable to meet an organism’s needs. You can think of this as the “address” where an organism lives. In contrast, a **niche** is the “occupation” of an organism. It defines the role of an organism in an ecosystem, such as a “fish-eating wader” for a heron, or a “plant-juice-sipping summer buzzer” for a cicada. An organism’s niche may change during different life stages. For example, a tadpole typically lives in the water and eats plant material, while the adult frog may catch insects from the shore.

The source of energy for all life on Earth is the sun. Green plants (and some bacteria) are the only organisms that can directly capture the sun’s energy and change it into a form that other organisms can use. Through the process of **photosynthesis**,



plants use sunlight to change carbon dioxide and water into sugar and oxygen. The oxygen is given off into the air, where it is available to other organisms including humans. Simple sugar molecules make energy available to plants and, by forming the basic units of complex carbohydrates, contribute to plant structure. Other organisms then eat the plants, or eat organisms that eat plants, and in doing so indirectly gain the benefit of the sun's energy to run their bodies. The flow of sunlight energy is therefore passed from producers (green plants) to primary consumers (animals that eat plants, such as leafhoppers) to secondary consumers (animals that eat other animals, such as birds); this sequence is known as a **food chain**. As energy is passed along the food chain, much is used up at each level as it works to run each organism. This energy is given off as heat and results in less energy being available at each stage along the food chain. It takes a lot of grass to support one rabbit, and many rabbits to support one hawk. As a consequence, there are many, many green plants on the Earth, fewer animals that eat plants, and even fewer animals that eat animals; this is known as the **energy pyramid**. In the bosque, the cottonwoods and other plants trap the sunlight energy and provide it in a form usable by the entire collection of other organisms found there. They provide the foundation for life along the river.

Although sunlight energy is used up as it is passed along the food chain, fortunately there is an abundant supply of this energy. In contrast, the materials from which all living things are made are limited in supply and must be used over and over. The primary building blocks of all living things include only six materials: carbon, hydrogen, oxygen, nitrogen, phosphorus and sulfur. When an organism dies and decomposes, these materials are returned to the system and are used again. The carbon that was once part of a dinosaur's tail may now be in the tomato that you eat for dinner! If these compounds are removed from the cycle in some way, they may become limited in supply. For example, if a tree dies but the wood does not readily decompose, carbon and other nutrients are trapped in the wood and are not available to other organisms. This appears to be happening in the bosque. Without the annual flooding that once inundated the forest, wetting the fallen wood and increasing the rate of decomposition, undecomposed wood is now building up and trapping nutrients. This affects the health of the entire ecosystem.

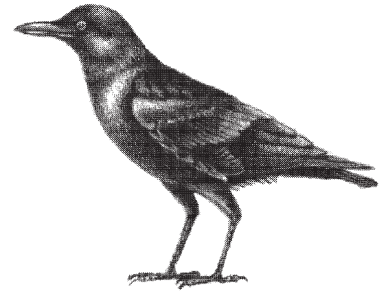
One very important cycle is the water cycle. Rain that falls on a hillside percolates down into the ground water, or may flow aboveground into a lake or the ocean. Water in the lake or ocean then evaporates, and drops join together into clouds, to eventually fall again as rain. Our use of water greatly affects the water cycle. In New Mexico we remove water from the underground **aquifer** (water present in the bed-rock below ground) much faster than it is replenished. Much of this water evaporates directly into the atmosphere while we use it, and may then fall again somewhere else on the planet, thus reducing the amount of water available locally.

We also impact the cycling of materials by introducing poisons. As materials are cycled over and over, toxins build up. Concentrations of toxins increase along food chains, since a predator eats many prey with the toxin, a process known as **biomagnification**. These increasing concentrations of toxins often have devastating



effects. Some well-known examples include top-predator species such as bald eagles and peregrine falcons that nearly became extinct due to the effects of DDT or other chemicals. Awareness of these problems may go a long way towards helping to keep our cycles clean.

Through the flow of energy and the cycling of materials, all living things are interrelated. A mouse not only gets energy from the seeds that it eats, but also gets materials that will help to build more mouse tissue. The mouse breathes out carbon dioxide which is taken in by plants, which in turn give off oxygen used by the mouse. The mouse also depends on plants for finding shelter, and it provides food for a snake or owl. The components of the bosque are interrelated with connections extending to the surrounding uplands as well. Some connections are obvious, such as birds that fly between the bosque and uplands at different times of day or during different seasons, moving materials from one place to another. Others are more subtle, such as water flowing underground. But these connections make our actions even more important. Pesticides applied to our fields may add toxic materials to the river, affecting not only the water itself but also all the organisms that depend on that water.



Change is an integral part of the natural world. Changes may occur over geologic time, such as the transition of the Rio Grande from a series of lakes to the river that we know today, or they may occur over much shorter time periods, such as the transition of a seed to a tree and finally to a fallen log. Change was once an integral part of the natural Rio Grande riparian ecosystem, as the river wandered across the floodplain leaving behind its ever-changing mosaic of vegetation. However, human-induced changes have much different effects on the ecosystem. The rate at which we are causing changes on Earth is much greater than has been known previously, and we do not yet know the ecological consequences of most of our actions. By understanding the ecological systems in which we live, and how we interact with them, we can begin to lessen our impact on Earth.

Biodiversity and Conservation

Two phrases that have become commonly used by biologists and natural resource managers, and now also by policy makers, the media and the general public, are biological diversity (typically shortened to biodiversity) and biological integrity. These phrases represent concepts that are critical to developing strategies for the preservation of biotic systems, yet they are often used imprecisely, without a true understanding of the underlying concepts. The Office of Technology Assessment, in a report titled "Technologies to Maintain Biological Diversity," defines **biological diversity** as "the variety and variability among living organisms and the ecological complexes in which they occur." Thus biological diversity, or biodiversity, is really much more than just the species richness (the number of species) or species



diversity (a measure of both the number of species and their relative abundances) at a given site. Biological diversity is a more comprehensive concept that considers several types of classification. For example, we can consider not only the number of species at a site, but also the representation of different higher levels of taxonomic classification such as the number of families or orders present. Likewise, we can consider genetic variability within a population or among different populations. Genetic variation among populations is reflected in “subspecies” designations, and these local populations or subspecies are often threatened or endangered. Finally, we can consider ecological diversity at a number of different levels. One example of this is the number of ecosystems represented within a landscape, such as the presence of the habitat mosaic within the Middle Rio Grande Valley. All of these concepts are important when considering biodiversity.

Biological integrity refers to the wholeness of a system, which includes the presence of all of the appropriate components and of all appropriate processes. Thus not only must the correct native species of plants, animals and microorganisms be present, but also the numerous processes, such as nutrient cycling or energy flow, should be occurring at their correct rates. This reflects the capacity of the system to recover after disturbances. The biological integrity of the Rio Grande riparian forest has been greatly compromised since the water in the river has been regulated. Natural processes such as flooding, which affects, for example, rates of decomposition of dead plant material and recruitment of young woody plants, have been altered. Thus the riparian forest now is not self-sustaining. Conservation and restoration efforts focused on promoting the biological integrity of a system are much more effective than those designed simply to save individual species. This is an important concept along the Rio Grande.

Keystone species are important to the maintenance of local biodiversity. A keystone species is a species that has strong regulatory effects on the composition of the community, even though it may be in relatively low abundance compared to other members of the community. The presence of the keystone species in some way determines which other species of organisms can be present. For example, in montane river systems beavers act as keystone species through their engineering feats: the construction of beaver dams and ponds creates habitat for many other aquatic plants and animals. When beavers are removed, the ponds are not maintained and many other species are eventually lost. Other examples are large herbivores such as elephants and rhinos in the African savannas, sea otters in the great kelp forests off the western coast of North America, and starfish in the intertidal zone. In the local bosque, the Rio Grande cottonwood is considered a keystone species because it provides the physical structure for the forest itself. Without cottonwoods, certain species of animals, such as cavity-nesting birds or insects that feed on cottonwoods, will not be supported. The presence of the cottonwoods creates the physical conditions that allow other bosque plants to grow. A complete loss of cottonwoods will certainly change the structure and composition of the local riparian forest.