Chapter 6

Fire in the Rio Grande Bosque

Fire in the Bosque

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Fire in the bosque! Dry weather and a changed bosque ecosystem have made this a common cry in recent years. Large bosque fires have increased public awareness of this fragile ecosystem, but there is still much to learn about riparian fires. Even land managers are still trying to understand the role that fire plays here and the best ways to protect bosque plants and animals. Just what do we know?

Fire in the Southwest

Fires are quite common in the southwestern U.S., particularly during the normally dry late-spring-to-early-summer season. In addition, regional fire patterns are tied to the El Niño–Southern Oscillation (ENSO) cycles: many large fires typically occur throughout the region during years influenced by the dry La Niña phase, when precipitation is well below average. Since the early to mid-1900s, the frequency of dry summers has increased, there have been more human-caused fire ignitions and fuels have accumulated due to fire suppression. Consequently, frequency, size and severity of fires in the region also appear to be on the increase.

Until recently, fire suppression was the goal of wildland resource management. Land managers now recognize the important role of fire in many of our natural ecosystems. In grasslands and ponderosa pine forests, for example, periodic disturbance from fire is important. Plants in these ecosystems have adaptations to survive fires, and they respond quickly after these events, by re-sprouting or releasing seeds. Many species fully depend on fire for regeneration. Fire also helps to break down nutrients from standing plant material and returns them to soil, making them more available for future plant uptake.

This fire burned rapidly in the bosque south of the Interstate 25 bridge near Isleta on March 23, 1996, a very windy day. Photo by Tish Morris.

The role of fire in lowland riparian forests of the arid Southwest, however, is not well known. Although the Rio Grande bosque must have experienced fires, it seems likely that fire was not an important part of this system prehistorically. Native Americans may have burned the bosque occasionally to clear for agriculture, and grassland fires may have burned into the riparian zone from surrounding uplands, but fires would have been less severe than they are today due to lower fuel supplies. Before people altered the river and decreased the frequency and extent of flooding, flooding promoted decomposition of leaves and wood, and thus decreased accumulations of fuels available for fires. In addition, flooding dampened the forest floor and thus directly inhibited fires. Since humans have altered the natural flow regime along the Rio Grande, the decrease in flooding has resulted in an increase in fuel loads, and subsequently fires, in the bosque.

These lowland riparian bosques are adapted to disturbance, particularly to flooding and herbivory by animals such as beavers, but it is unlikely that fire was among the important forces shaping the evolution of Rio Grande cottonwoods. Re-sprouting is a common adaptation among some cottonwood species to disturbance by flooding and by other forms of severe defoliation (loss of leaves). Cottonwoods can re-sprout from their roots and from the base of the trunk after light fires, but in severe fires, mature tree mortality is very high. Typically, all above-ground tissues are killed in severe fires. Other plants native to Rio Grande riparian bosques also can re-sprout after less severe fires, including species such as seepwillow, New Mexico olive and Goodding's willow. However, long-term data on post-fire survival for these species are unavailable, so our understanding of fire in this ecosystem remains limited.

Over the last century, non-native plants have flourished in the bosque, bringing different dimension to fires that occur there. Some non-native plants, particularly saltcedar, also sprout well after lighter fires. Further, the accumulation of the very flammable leaf litter from saltcedar is thought by some researchers to promote fires. Although the leaves contain volatile oils, they also tend to have a high moisture content, so it is the accumulation of leaf litter and dead woody material within the plants that increases flammability. One consequence of severe fires that kill the large cottonwoods is that after the mature trees fall, clearings are created that provide habitat for the establishment of new trees. Prior to the invasion by saltcedar and alteration of the river's flow, these clearings would have been flooded and colonized by young cottonwoods and other native plants. Today, however, they are more often colonized by saltcedar, which releases seeds over a longer period of time and can take advantage of late-summer rains for establishment. Further, saltcedar has been observed to flower more heavily after a fire (stress-induced flowering), which increases the production of seeds available to colonize these clearings. Thus saltcedar may both promote and benefit from large fires in the bosque.

What Makes a Fire?

Fire needs three elements to burn: heat, fuel and oxygen. These three elements make up the *fire triangle*, and all three must be present for fire to ignite and spread. The initial heat is provided by an ignition source, for example a lightning strike, a lighted cigarette or a stray firework. This source of ignition must find sufficient fuel to burn, such as dry leaves and grasses, dead trees or fallen branches; there must be both something that lights easily to start the fire and a sufficient quantity of fuel to maintain it. Oxygen is readily available in the air. Weather conditions can affect the likelihood of a fire occurring. Hot temperatures and dry winds—conditions typical of late spring and early summer in New Mexico—promote the spread of fire, while fires are less likely to occur in cold and wet conditions.

How Do We Fight Bosque Fires?

The Rio Grande bosque is part of both urban and agricultural communities and is a wildland–urban interface where fire in one threatens the other. A house fire can start a bosque fire, and a bosque fire can start a house fire. Reducing fire risk in the bosque is an important part of protecting adjacent communities. The Wildland Fire Task Force of the City of Albuquerque is charged with suppressing any wildland fires that occur within the Albuquerque city limits and surrounding areas. The task force includes personnel and equipment from six fire stations that are located either by the Rio Grande bosque or on the east or west mesas. These personnel are specifically trained to fight wildland fires. Fire-fighting equipment used by this crew includes front-line emergency response equipment as well as two brush trucks (one capable of foam production) and two four-wheel-drive all-terrain vehicles (with a towing trailer). These crews are also equipped with personal protective equipment, portable drafting pumps and hand tools designed for wildland or brush fire fighting. Similar equipment is used by crews along other reaches of the Middle Rio Grande Valley.

Fires in the bosque provide some unique obstacles in suppression. The primary constraint is due to restricted access within the levees. Jetty jacks represent very real obstacles to fire fighting access—trucks cannot get into much of the bosque area due to jack lines. Only smaller trucks are able to follow levee roads. Hand crews face problems, too—Russian olive and black locust have very painful thorns!

Fire suppression techniques depend in part on the size of the fire. With flames up to three feet (1 m) high, firefighters can fight the fire directly with hand equipment. Bulldozers are used to fight flames that exceed three feet, up to 12 feet (1–4 m). Water drops from helicopters and cargo planes are used when flames exceed 12 feet (4 m).

Recent Fires in the Bosque

Today, fires in the bosque tend to be caused by humans, with lightning-caused fires being relatively rare. During a 10-year study period (1986–1995), UNM graduate student Mary Stuever found that most fires in the Middle Rio Grande bosque occurred between February and April, though in some years there was an increase in mid-summer and/or fall fires. One of the main causes of bosque fires—debris burning—typically occurs during the late-winter to early-spring period when farmers are preparing fields and acequias for the growing season. Other common causes of bosque fires include arson, illegal campfires, children and careless disposal of smoking materials.

New Mexico State Forestry Division data show that 534 fires occurred on Middle Rio Grande Conservancy District lands in the Middle Rio Grande Valley during 1993–2003, with fires burning in all months of the year. By far most fires occurred during February through July. Very large fires were not common; only 4 percent of all fires burned over 100 acres (40 ha*), with most fires (82 percent) less than 10 acres (4 ha) in size, and 14 percent of all fires burning between 10 and 99 acres (4 and 39.6 ha). All fires that burned over 100 acres (40 ha) occurred during March through June, with 13 of these 23 fires occurring in April. Most of these large fires burned in Socorro County.

Post-fire recovery work in the Valley has changed over the years as our understanding of the system and management options has grown. Initially, burned sites were simply left alone, with no post-fire restoration attempted. Later, restoration work focused on replanting native trees into large monocultures, with no effort to plant understory shrubs or grasses. Burned stumps were ground out and removed. Now there is more of an attempt to restore the mosaic of habitats once present in the valley. In addition to pole-planting cottonwoods and willows, workers plant understory shrubs and spread seeds for native grasses. Stumps of native species are left to re-sprout and constructed wetlands may be added. Heavy machinery is often used to remove burned wood from sites or to chip remaining wood. Herbicides are sometimes used to kill stump-sprouts of exotic species such as saltcedar, with follow-up treatments in subsequent years. Remaining live native trees are protected and some dead snags are left for habitat enhancement, providing homes for wildlife. Some sites are now monitored after restoration efforts are completed to measure progress and gauge the success of the project.

* ha = hectares, a metric unit of area equal to 10,000 square meters or 2.471 acres

Managing for Fire Prevention

Changes in bosque management are needed to decrease the impact of fires. Researchers and land managers have finally come to a seemingly radical approach to the preservation and restoration of Rio Grande bosque after more than a decade of work focused on understanding this dynamic ecosystem. Published in 2005, the Bosque Landscape Alteration Strategy (BLAS) was developed by numerous scientists, land managers and others interested in preserving the bosque. The strategy focuses on re-creating a patchy mosaic of native riparian trees and open spaces along the narrow active floodplain, within the current levee system, between Cochiti Dam and the upper end of Elephant Butte Reservoir. The goals of this rehabilitation/remediation/restoration strategy are to decrease the potential for bosque wildfires and to decrease water loss due to evapotranspiration, while trying to replicate the mosaic of habitats once present along the Middle Rio Grande Valley. The strategy will reduce the now often-continuous forest into patches of trees interspersed with meadows and wetlands. Active implementation of the BLAS should result in a very different floodplain than the one we know today, but this will be a landscape more like that present prior to human intervention and one much less prone to devastating wildfires.

The BLAS provides new guidelines for bosque management, which are being incorporated by numerous agencies actively working to reduce the potential for and the impact of fires in the bosque. One multi-agency restoration plan already underway, the *Bosque Wildfire Project*, involves the U.S. Army Corps of Engineers, the City of Albuquerque Open Space Division, the Middle Rio Grande Conservancy District, the Corrales Bosque Preserve, Village of Corrales, the Pueblo of Sandia, the Pueblo

Two and a half years after the 2003 fire near the Bernardo/U.S. 60 bridge, the devastation was apparent. Photo by Mark B. Higgins.

of Isleta, the New Mexico State Forestry Division and others. The project seeks to selectively thin areas with high fuel loads and/or non-native vegetation, to remove jetty jacks and debris, to improve emergency access (drain crossings, levee road improvements and construction of turn-arounds) and to revegetate burned and thinned areas. The project area includes the Albuquerque Reach of the Rio Grande bosque (also known as the Rio Grande Valley State Park), the Corrales Bosque Preserve and locations within the Pueblos of Sandia and Isleta. Similar work is being done by the Socorro Save Our Bosque Task Force for Socorro County, as well as at other sites along the valley.

One of the main strategies used now to prevent fires is the removal of non-native vegetation and dead and down woody debris from areas that have not burned. This involves large-scale removal of dead trees and fallen branches using heavy equipment such as brush cutters and Bobcats; the wood is typically either removed from the site and offered to the public as firewood or chipped and spread across the site in an attempt to restore nutrients to the forest. This fuel load reduction, however, has brought mixed reactions. While it appears that decreasing accumulations of woody debris on the forest floor and removing non-native shrubby plants will decrease the potential for devastating fires and help to protect native cottonwoods, this also removes habitat for certain native animals. In particular, there has been controversy over removing habitat for shrub- and ground-nesting birds. Studies have shown that overall bird species richness is enhanced by the presence of a variety of habitats within the bosque corridor—such as the presence of sand bars and meadows, thick brushy understory, mid-level shrubs, as well as mature trees. There has been concern that removing understory vegetation and woody debris will remove much of these available habitats. Some clearing is being done in stages over several years to allow native plants to get established in partially cleared areas before all non-native plants are removed. Certainly it is important that clearing is done during the non-breeding season to protect nesting birds. Clearing done during the breeding season causes nest abandonment and can directly kill birds. Revegetating with native shrubs will be important to maintain the shrub habitat needed by certain avian species.

One message concerning the bosque is clear from the recent increase in wildfires: a healthy bosque will not survive without active intervention and management and indeed without drastically new management practices. Perhaps ironically, what is needed are changes that approximate the structure and functioning of the old system—albeit within the spatial constraints of the present system—and a reduction of regulatory activities that impact the river's natural flow regime. We now know that we must take our lessons from the river itself and restore or rehabilitate what we have changed, in order to save this unique ecosystem.

Selected Bosque Fires

To best understand the effect of fire in the bosque, it is helpful to visit a burned site. The following is a summary of some recent and better known fires in the Middle Rio Grande Valley (information from the City of Albuquerque Open Space Division, the Middle Rio Grande Conservancy District and the Bosque del Apache National Wildlife Refuge). Look at the *Bosque Education Guide* web site for additional sites.

Montaño Fire

When: June 25, 2003

Where: Montaño Bridge at all quadrants. Source of fire was from the northwest section.

Size: 113 acres (46 ha)*. The northwest quadrant burned 67 acres (27 ha). Started on public land and spread to private land.

Cause: Human-caused (cigarette)

Recovery work: Large burned trees were cut down and cut into firewood-size pieces. Most of the wood was made available to the public as free firewood. There was less chipping in this area compared to the I-40 fire (see below). Larger open areas were seeded with native grasses and cottonwoods were pole-planted. Exotic stump re-sprouts were sprayed with herbicide. Native stump re-sprouts were caged to protect against beavers. Open Space Division and students are monitoring on-going recovery.

I-40 (Atrisco) Fire

When: June 24, 2003

Where: On both sides of the river, mostly north of the I-40 bridge, to just south of Campbell Road (south of the Nature Center Discovery Pond)

Size: 150 acres (61 ha). Started on public land, spread to private land

Cause: Human-caused (fireworks)

Recovery work: Large burned trees were cut down and most of the wood was chipped and spread on the ground. Some larger pieces were offered to the public as firewood. Some cottonwood and willow poles were planted. Larger areas farther from the water table were seeded with native bosque grasses. Exotic re-sprouts from stumps were sprayed with herbicide while native re-sprouts were protected with beaver caging. Open Space Division and students are monitoring recovery.

* ha = hectares, a metric unit of area equal to 10,000 square meters or 2.471 acres

La Orilla Burn

When: April 23, 2002

Where: West side of river between La Orilla and Paseo del Norte

Size: 35 acres (14 ha)

Cause: Human-caused (illegal campfire)

Recovery work: Burn recovery included 1,100 new trees and shrubs planted in the burn area. Replanting was a coordinated effort between the City Open Space Division, Tree New Mexico, schools and other volunteer groups.

San Pedro Fire

When: June 8, 1996

Where: Near the community of San Pedro, north of Bosque del Apache National Wildlife Refuge. The fire burned south and into the refuge.

Size: Approximately 6,000 acres (2,428 ha) total, with 1,640 acres (656 ha) within the Bosque del Apache National Wildlife Refuge

Cause: Human-caused (arson)

Recovery work: (This summary is based primarily on work done within the Refuge.) Recovery work includes extensive exotic control, using an excavator to remove root crowns with little soil damage, clearing with root plows and root rakes and treating sprouts with herbicides. Cross dikes and water delivery systems were added in some places to manage water levels and promote native tree germination. Refuge personnel, along with members of the Socorro Save Our Bosque Task Force, developed a conceptual plan for restoration of the whole valley (Socorro area), including San Pedro burn areas. Other procedures include monitoring physical and biological aspects of the system and removing some of the man-made infrastructure.

* ha = hectares, a metric unit of area equal to 10,000 square meters or 2.471 acres

A Glossary of Fire Terms

Canopy is the uppermost branches of trees forming a continuous cover of leaves at the top of a forest.

Crown fire is a high-severity fire that reaches up into the forest canopy.

Fire adaptation is a characteristic that enhances the ability of an organism to survive fires.

Fire break or *fuel break* is a natural or man-made barrier that lacks fuel sufficient to maintain a fire.

Fire dependence refers to natural communities that are adapted to fire and that rely on fire for maintaining conditions needed by plants and animals in those communities. Such a system may be called a *fire-dependent ecosystem*.

Fire ecology is a branch of ecology that studies the origins of wildland fire and its relationship to the ecosystem.

Fire history indicates how often fires occur in a given geographical location.

Fire-independent ecosystem is a system that does not have fires at all, either because there is no ignition source or due to a lack of vegetation.

Fire intensity is a measure of heat generated by a fire. This can only be measured during the fire, so typically fire severity (see below) is a more useful measure when making observations at a site after it has burned.

Fire regime reflects the characteristics of fire in a given ecosystem over time, such as the frequency, predictability, intensity and seasonality of fire. This is basically the role that fire plays in that ecosystem.

Fire scar is a mark on a tree produced by a layer of charcoal (a burned layer) that is then enveloped by a layer of new growth.

Fire-sensitive ecosystem is a system that evolved without the influence of repeated fires, in which the plants and animals generally lack adaptations to come back after fires.

Fire severity is a measure of the degree to which a fire alters a given site. Fire severity can be determined after a fire, based on characteristics such as the extent of burn (char) on a tree or the amount of leaf litter remaining on the ground, and this is used to estimate the effects of fire intensity.

Fire triangle indicates the three elements needed to start and maintain a fire: heat, fuel and oxygen.

Fuel ladder is dry or volatile plants of different heights that carry fire up to the tops of trees, such as fallen trees, branches or exotic plants (saltcedar, Russian olive).

Ground fire is a fire burning on the ground or through the understory and not reaching into the canopy.

Prescribed burn/prescribed fire is a fire intentionally set under known conditions of fuel, weather and topography to achieve a specific management goal.

Reclamation is the act or process of bringing wild or waste land into a condition for productive use, or repairing an area after activities such as mining or fire (typically modifying an area to be of some use to humans).

Restoration is the process of restoring an area to its natural condition (or a condition that mimics the natural condition as nearly as possible).

Topography is the surface features of a place, the contours of a landscape large or small.

Wildfire is a non-structural fire (not in a building), other than a prescribed fire, that occurs in a forest or other wildland area.

Wildland–urban interface is land close to or within forested area that contains houses and other buildings.

References

Bosque Landscape Alteration Strategy Objectives, Basic Requirements and Guidelines. 2005. Yasmeen Najmi, Sterling Grogan and Cliff Crawford. Middle Rio Grande Conservancy District, Albuquerque, NM.

Resources

The Corps of Engineers has a web site with maps of burned areas: www.bosquerevive.com/FireRestoration/projectMaps.htm

The New Mexico State Forestry Division maintains a list of bosque fires at www.emnrd.state.nm.us.

41. *Fire Vocabulary Match-up*

Description: Students find the classmate who has the right definition to match their vocabulary word in a simple game.

Objective: Students will learn new vocabulary related to fire ecology.

Materials: Copies of the attached vocabulary words and definitions, cut into cards and laminated if possible.

Procedure:

1. Split the class into two groups. There are 30 individual cards (15 words); remove pairs of words if needed.
2. Hand out the definition cards to one group and the vocabulary cards to the second group, making sure the cards are well shuffled.
3. Instruct students to find their partners or the student who has the definition to match their vocabulary word or vice versa.
4. Once students have found their match, assemble the group into a circle (if possible).
5. Allow student pairs to take turns presenting their word and definition to the rest of the class. Take time to answer any questions from the students and draw pictures or diagrams on the chalkboard to help illustrate the term and its meaning.
6. Create a list of the words on the board as students make their presentation.
7. Instruct students to copy the list down in their notebooks with the best definition for each term that they can remember.

41. Fire Vocabulary Match-up

Grades: 4–12

Time: Preparation time 30 minutes; activity time 30–45 minutes

Subjects: science

Terms: *ecological disturbance, ecological succession, fire adaptation, fire dependence, fire ecology, fire intensity, fire regime, fire scars, fire severity, fire triangle, food web, habitat, natural fires, wildfires, fire break*

Key:

- ☐ *crown fire*—high-severity fire that burns whole trees, moving from tops of trees to other trees
- ☐ *fire adaptation*—a characteristic that enhances the ability of an organism to survive natural fires
- ☐ *fire break (fuel break)*—a natural or man-made barrier that lacks sufficient fuel to maintain a fire
- ☐ *fire dependence*—the concept that fire is essential to many plant and animal communities
- ☐ *fire ecology*—a branch of ecology that studies the origin of wildland fire and its relationship to the ecosystem
- ☐ *fire history*—a measure of how often a fire occurs in a given geographic location
- ☐ *fire intensity*—a measurement of heat generated by a fire
- ☐ *fire regime*—the different role fire plays in different ecosystems including the frequency, predictability, intensity and season of fire
- ☐ *fire scar*—a mark on a tree produced by a layer of charcoal that is then enveloped by a layer of new growth
- ☐ *fire severity*—a measure of the degree to which a fire alters a given site
- ☐ *fire triangle*—the three elements needed to start and maintain a fire: heat, fuel and oxygen
- ☐ f*uel ladder*—dry, dead or volatile plants of different heights that carry fire up to tops of trees
- ☐ *ground fire*—low-severity fire that burns quickly across the ground
- ☐ *prescribed burn/prescribed fire*—a fire intentionally set under known conditions of fuel, weather and topography to achieve a specific management goal
- ☐ *wildfires (wildland fire)*—any non-structural fire (not in buildings) other than a prescribed fire, that occurs in a forest or other wildland area

Thanks to the Student Ecology Research Program. January 2005. New Mexico Museum of Natural History & Science.

crown fire

High-severity fire; fire that burns whole trees, moving from tops of trees to other trees

fire adaptation

A characteristic that enhances the ability of an organism to survive natural fires

fire break (fuel break)

A natural or man-made barrier that lacks sufficient fuel to maintain a fire

fire dependence

The concept that fire is essential to many plant and animal communities

fire ecology

A branch of ecology that studies the origin of wildland fire and its relationship to the ecosystem

fire history

A measure of how often a fire occurs in a given geographic location

fire intensity

A measurement of heat generated by a fire

fire regime

The different role fire plays in different ecosystems, including the frequency, predictability, intensity and season of fire

fire scar

A mark on a tree produced by a layer of charcoal that is then enveloped by a layer of new growth

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fire severity

A measure of the degree to which a fire alters a given site

fire triangle

The three elements needed to start and maintain a fire: heat, fuel and oxygen

fuel ladder

Dry, dead or volatile plants of different heights that carry fire up to tops of trees

ground fire

Low-severity fire that burns quickly across the ground

prescribed burn/ prescribed fire

A fire intentionally set under known conditions of fuel, weather and topography to achieve a specific management goal

wildfire

Any non-structural fire (not in buildings) other than a prescribed fire, that occurs in a forest or other wildland area

42. A Spectrum of Fires

Description: Teams of students create posters to illustrate the role of fire in different ecosystems.

Objective: Students will learn how fire in the bosque is different from fire in mountain forest or grassland areas.

Materials: Cards for each ecosystem, poster board or large paper, markers and/or crayons, books describing different ecosystems, pictures of different ecosystems or access to Internet to look up ecosystems and role of fire

Background: Although for many years Smokey Bear taught us that wildfires are bad for forests, we now understand that fire plays a natural role in many ecosystems. Some ecosystems are highly adapted to reoccurring fires, with plants and animals that not only survive this disturbance, but in many cases may require it in order to reproduce. The role that fire plays in an ecosystem, reflecting the frequency, predictability, intensity and seasonality of fire, is known as the *fire regime*. The fire regime describes the characteristics of fire in a given ecosystem over time. Fire regimes vary greatly across different ecosystems and can change when humans alter the way a system functions.

Prior to human intervention, fires were once a major form of ecosystem disturbance in tropical and temperate grasslands, temperate woodlands and shrublands, as well as in many types of forests. These are *fire-dependent ecosystems*—they are resilient to repeated fires and have plants and animals that may depend on fire to re-

42. A Spectrum of Fires

Grades: 6–12

Time: two class periods

Subjects: science, art, social studies

Terms: *cambium, crown fire, exotic species, fire adaptation, fire break, fire regime, fire-dependent ecosystem, fire-sensitive ecosystem, fire-independent ecosystem, fire suppression, fuel ladder, mosaic distribution, nutrient cycling, plant clone, succession*

produce. In the U.S., there are a number of vegetative communities adapted to fire. Examples of these include the tall-grass prairie of the Midwest, the chaparral (brushland) of California and the Southwest, ponderosa pine forest of the interior West, Douglas fir forest of the Pacific Northwest, boreal forest of Alaska, loblolly and shortleaf pine forest of the Southeast and jack pine forests of the Great Lakes states. Some examples from other regions of the world include the eucalyptus woodlands in Australia, the South African fynbos and the tropical savannahs of South America, Africa and Australia. In these ecosystems, fire determines which plant species can survive and sculpts the structure of the ecosystem itself. For example, in temperate grasslands like the Great Plains, fire favors the growth of grasses and forbs, while excluding woody vegetation. When fire is removed through human interference, woody plants invade and grasslands slowly give way to forest. Many prairie wildflowers have become endangered as a result of fire suppression.

Fire is a key ecological process in the Southwest. In New Mexico, fire plays an important role in desert grasslands, piñon-juniper woodlands, ponderosa pine forests and mixed-conifer forests (containing Douglas fir, white fir, blue spruce, Gambel oak and quaking aspen).

Plants in fire-dependent ecosystems have numerous adaptations to survive fires. A *fire adaptation* is a characteristic of an organism that enhances its ability to survive a fire. These include:

- Bark thickness: thick, tough bark acts as insulation to protect the tree against fire. Examples are ponderosa pine, Douglas fir, longleaf pine, slash pine, burr oak, giant sequoia.
- Underground roots and tubers: small woody plants and shrubs, as well as trees with thin bark, use the soil to protect their underground roots and tubers, from which they can produce shoots after a fire. Examples include aspen, willow, northern pin oak, fireweed, prairie grasses.
- Protected buds: some plants can re-sprout from buds that are protected within foliage (such as the buds of longleaf pine which are protected within thick clusters of needles) or within the main stem or branches.
- Fire-resistant seeds: these seeds are able to withstand the fire and fall into the nutrient-rich ash, from which they germinate when sufficient water is available.
- Serotinous cones: cones that will not open to release seeds until a fire occurs. Serotinous cones are held closed by a resin that only opens when a critical temperature is reached, requiring the high heat of a wildfire. An example of this is the jack pine. Some pine species, such as lodgepole pine,

have cones that can vary from serotinous to free-opening, depending on whether the tree is growing in an area with frequent fires. In areas where fires are infrequent, a lodgepole pinecone can open and release its seeds even without the fire.

Many animals can flee in the face of a fire, either by flying or running away. Large animals such as deer, bear, coyote, fox or kangaroo can typically run or jump out of harm's way. Smaller animals such as mice, shrews, lizards, snakes and tortoises burrow underground to escape. Adult birds can fly away, but their young usually cannot escape. Some predators take advantage of fires to hunt along the edges for other species fleeing the flames. The jewel beetle (genus *Melanophila*), also known as the black fire beetle, is actually attracted to fires, using infrared detectors to find its way to a source of heat. They can travel many kilometers to reach a forest fire, where they join a mating frenzy and lay their eggs on a charred stump or log. The young are able to eat the newly dead wood when they hatch out.

In contrast to fire-dependent ecosystems, *fire-sensitive ecosystems* evolved without the influence of repeated fires, and plants and animals generally lack adaptations to come back after fires. Rainforests throughout the world are examples of this type of ecosystem. *Fire-independent ecosystems* tend not to have fires at all, either because there is no ignition source or due to a lack of vegetation. This type includes the Namib desert of southern Africa and tundra ecosystems of coastal Antarctica.

Unfortunately, humans have changed the role that fire plays in many ecosystems, either by suppressing fires where they naturally occur or by adding fires to systems that are not adapted to them. The U.S. Forest Service had a policy of fire suppression for 60 years, based on the mistaken belief that fires were harmful to the forests. In addition, the introduction of widespread grazing in the west, beginning in the late 1800s, decreased the cover of grasses that helped spread low-intensity ground fires. The result has been huge, catastrophic fires in forests that had tremendous fuel build-up in the absence of low-intensity ground fires. This has led to a shift in species composition of grasslands and forests. For example, stands of quaking aspen, which typically colonize burned sites in mixed-conifer forests, have declined in New Mexico due to fire suppression.

In the case of the bosque, changes in floodplain moisture, due to the suppression of periodic flooding, have resulted in a build-up of fuels, while increased human activity in and around the bosque have increased sources of ignition. The result has been catastrophic

fires in an ecosystem that was not adapted to large fires. We now understand the need to manage the bosque in a way that will decrease the impact of wildfires. Land managers are removing dead and downed wood and exotic species such as saltcedar and are trying to restore the mosaic of habitats that once provided natural fire breaks in the floodplain. It is hoped that these changes will decrease the effects of wildfires in the bosque.

Procedure:

1. Discuss the meaning of fire regime and differences among fire-dependent, fire-sensitive and fire-independent ecosystems worldwide. Show pictures, from a web search or from books, of the different types of ecosystems described above (Background).
2. Introduce students to the eight New Mexico ecosystems used in this activity (Rio Bravo, Rio Manso, Rio Nuevo, southwest grasslands, piñon–juniper, ponderosa pine, mixed conifer and subalpine conifer), using photos or pictures to illustrate differences. Note to teachers: to understand the differences between the bosque and upland systems, the non-bosque ecosystems are all presented as they existed without major fire suppression. Most of these systems today have been affected by long-term fire suppression (see #7).
3. Separate students into eight cooperative learning groups so there are two or three students per ecosystem. Hand out the descriptions of fire regimes. Each description includes the following and should be included on the student's poster:
   a. Environment: the general environment with a description of the ecosystem
   b. Ignition: typical sources of fires
   c. Fire frequency: how often fire will move through, may include the season
   d. Type: are fires typically ground or crown fires?
   e. Plant effects: fire's effect on the plants and/or plant adaptations to recover after fire
   f. Unique factors: interesting information about fire in that ecosystem
4. Each group reads how fire interacts with the ecosystem described on its card.
5. Give students poster board or large paper, markers and/or crayons. Instruct them to illustrate how fire changes their ecosystem. They can use words to describe or label any part of the drawing.
6. Have each group share their poster with the rest of the class.

7. Discuss as a class which ecosystems are dependent on fire or sensitive to fire. Discuss the effects of fire suppression in ecosystems adapted to low-intensity ground fires. The bosque has had the influence of major fires introduced into the ecosystem, while grassland and upland forests of New Mexico have been altered by the absence of fire.

Discussion Questions:

Which ecosystems are dependent on fire or are sensitive to fire?

What is the effect of fire suppression on each ecosystem?

What factors increase or decrease fire intensity in that ecosystem?

What is the effect of fire suppression on ecosystems adapted to low-intensity ground fires?

Is fire good or bad? Where/ under what conditions is it "good"? Under what conditions is it "bad"?

Extensions: Look up the definition of "ecological succession." Compare succession in the different ecosystems and the role that fire plays in succession for each. Some will work well to illustrate a cycle.

Resources: New Mexico Department of Game and Fish "Life Zones of New Mexico" coloring book has information and line drawings. Available on line at www.wildlife.state.nm.us/education/index.htm

Thanks to the Student Ecology Research Program. January 2005. New Mexico Museum of Natural History & Science.

Rio Bravo Bosque

Fire Regimes

1. Environment: Before river regulation (upstream dams) and changes to the floodplain, the mature bosque probably existed in patches, called a “mosaic distribution.” Groups of large cottonwoods alternated with younger stands of trees and shrubs, open meadows, and wetlands. Mature forests probably had patchy understory due to regular flooding.
2. Ignition: Prehistoric fires were generally started by lightning strikes in adjacent grasslands, with wind often sending fire into the bosque.
3. Fire frequency: Fires in the prehistoric bosque were probably infrequent, occurring during the dry late spring to early summer (April through June), particularly in dry years.
4. Type: Fires were generally cool, ground fires that crept around the forest floor, sparing many cottonwood trees.
5. Plant effects: Cottonwoods and many native shrubs can re-sprout after light fires. The thick bark of cottonwoods protects them from debris during floods. Trees are damaged by even low heat from fires.
6. Unique factors: The mosaic of meadows, marshes and forests would have provided natural firebreaks that stopped the spread of wildfires. Regular overbank flooding would have aided decomposition of fuels and helped to clear out underbrush, reducing the fuel load. Flooding also would have kept fuels moist in the early summer. Altogether, there were fewer fires, and fires did not spread as much in past river environments.

1

Rio Manso Bosque

Fire Regimes

1. Environment: The changed bosque is a continuous forest of mature or dying cottonwoods, with dead wood and leaves on the ground and a brushy understory including exotic shrubs such as saltcedar and Russian olives.
2. Ignition: In addition to lightning, careless human activity provides many ignition sources.
3. Fire frequency: Fires in the changed bosque typically occur each year. Fires can occur in any month, but most occur in the late winter to early summer (February through June).
4. Type: Large amounts of dry fuel on the forest floor, along with exotic shrubs, cause very hot fires. Shrubs and fallen trees create vertical fuel ladders that carry flames up into the cottonwood canopy.
5. Plant effects: Cottonwoods can sprout after some fires. Exotic saltcedars are highly flammable due to the amount of leaf litter and dead woody material within the plants. They sprout easily after fires and can often produce seeds in the year following a fire, spreading into areas where cottonwoods have been killed.
6. Unique factors: Regulation (controlling the flow with dams) of the river and changes to the floodplain resulted in decrease or elimination of flooding. Without it, leaf litter and wood accumulate in the forest, providing more fuel for fires. Shrubby undergrowth also contributes to fire.

2

Rio Nuevo Bosque

1. Environment: The new bosque mimics the prehistoric bosque, but is restricted to the area within the levees. It includes stands of mature cottonwoods, with open, park-like understories. These alternate with stands of younger cottonwoods of varying ages, grassy meadows and wetlands, forming a “mosaic”: a patchwork of different vegetation.
2. Ignition: In addition to lightning, careless human activity causes ignition.
3. Fire frequency: Management to reduce standing fuels and remove exotics, along with public education, have decreased the frequency of fires. Fires can still occur annually and throughout the year due to human activity.
4. Type: Fires burning in “treated” stands (see #6) generally stay on the ground rather than moving into the tree tops. These fires move rapidly but generate less heat than crown fires. Untreated areas may still burn very hot and do considerable damage.
5. Plant effects: In light fires, few cottonwoods as fire creeps along the forest floor. Some of those killed above ground produce root sprouts.
6. Unique factors: Many places have been “treated”: the fuels in the new bosque have been removed or decreased to reduce damage should a fire start. The majority of the exotic understory (such as saltcedar or Russian olive) has been removed and native plants now form the understory. Managers allow overbank flooding in wet years; this reduces fire danger by increasing decomposition and moisture.

Fire Regimes

3

Southwestern Grasslands

1. Environment: Grasslands are extensive flat stretches of grass and other small plants.
2. Ignition: Lightning was a traditional source of fire; today, careless human activity provides additional ignition sources.
3. Fire frequency: Historically, grasslands probably burned every couple of years, typically in late winter through early summer, when dry dead grasses from the previous growing season were abundant.
4. Type: Fires move quickly across large areas, fueled by the dead grasses and gentle slopes typical of grasslands.
5. Plant effects: Grasses are able to regenerate after fires because their growing tissue is underground, at the base of the plant. Many grassland plants (such as wildflowers) also benefit from fires, sprouting from seeds that are able to withstand the burn.
6. Unique factors: Fire helps to maintain the grasslands by reducing the establishment of trees and shrubs. Fires release nutrients from litter (dead plant material) and accelerate the rate of decomposition in the soil, making important nutrients available for new growth. When fires are suppressed, shrubs and trees replace grasses.

Fire Regimes

4

Piñon-juniper Woodland

Fire Regimes

1. Environment: Woodlands, characterized by widely spaced small trees, occur below the forest and above the grassland or chaparral shrub zones. In the Southwest, the main trees are piñon pine and juniper. Where piñons dominate at higher elevations, native shrubs such as oaks also occur.
2. Ignition: Lightning was a traditional source of fire; today, careless human activity may provide additional ignition sources.
3. Fire frequency: Historically, low-intensity fires probably occurred every 10 to 30 years. Most fires occurred during late winter through the early-summer dry season. Today human activity means fires can occur during any month. Fire suppression in this habitat has been common, so in most areas there has not been a fire in decades.
4. Type: Surface fires burn quickly through the open, grassy spaces between piñons and junipers.
5. Plant effects: Ground fires burn dried grasses and other small plants and help to clear out smaller shrubby species. Piñons and junipers can withstand light fires.
6. Unique factors: These trees are drought tolerant, but water limitations, as well as fire, keep them well spaced. Relatively frequent, low-intensity ground fires help to maintain the piñon-juniper woodlands. Fires also help to cycle nutrients back into the soil, a particularly important function in such a dry ecosystem.

5

Ponderosa Pine Forests

Fire Regimes

1. Environment: Ponderosa pine forests historically contained large, widely spaced ponderosas, with grassy understory.
2. Ignition: Lightning was a traditional source of fire; today, careless human activity provides additional ignition sources.
3. Fire frequency: Prior to fire suppression, ground fires burned ponderosa pine forests every two to 12 years, particularly in the dry spring-to-early summer period.
4. Type: When fires burn regularly, they remain low-intensity ground fires. Since fire suppression, fires that do occur become hot crown fires that kill mature trees. Many areas have not burned in decades.
5. Plant effects: Ponderosa pine has thick bark, deep roots and no low branches. These factors increase its ability to withstand ground fires and decrease the possibility of a fire climbing to the crown; crown fires can kill ponderosa pines.
6. Unique factors: Frequent low-intensity fires historically did not reach into the canopy, but rather quickly burned the grasses, fallen wood and accumulations of pine needles on the ground. Such fires release nutrients into the soil and provide a good seedbed for ponderosa pine seeds. Seedlings are shade intolerant, doing well in sites that have been cleared by burning. The seedlings are vulnerable to fire, but at about five or six years of age, the tree begins to develop thick bark and deep roots that make them resistant to fires.

6

Mixed-conifer Forest

1. Environment: The composition of trees in mixed-conifer forests varies with elevation and location, but includes Douglas fir, white fir, blue spruce, Gambel oak, and quaking aspen. Understory plants include grasses, small plants (such as wildflowers) and shrubs.
2. Ignition: Lightning was a traditional source of fire; today, careless human activity provides additional ignition sources.
3. Fire frequency: Historically, fires occurred every five to 25 years. Since fire suppression, many areas have not burned in decades.
4. Type: Under natural conditions, fire in these forests varied from frequent ground fires to infrequent, patchy crown fires.
5. Plant effects: Most of these trees can withstand low-intensity ground fires. The less frequent crown fires would have killed the trees, leaving cleared areas. This allowed aspens to establish. Aspens spread through cloning: after a fire they can sprout from underground roots.
6. Unique factors: Low-intensity, quickly burning ground fires would have cleared out the understory and returned nutrients to the soil. Aspen groves within mixed-conifer forests tend to be short-lived; through the process of succession, conifers become reestablished within 10 years.

Fire Regimes

7

Subalpine Conifer Forests

1. Environment: These forests are dominated by Englemann spruce and subalpine fir, and in New Mexico occur on small, isolated mountaintops where snow covers the ground much of the year and the ground is usually damp through the short growing season. Stands of aspen also occur, particularly after fires.
2. Ignition: Fires are started by lightning, by fire moving up from lower elevations during dry years or by human activity.
3. Fire frequency: In some areas, historic fire intervals are 150 years or more. Some spruce-fir forests experience low-intensity ground fires every five to 30 years, depending on surrounding ecosystems.
4. Type: Fires tend to be intense crown fires that kill mature trees.
5. Plant effects: Spruce and fir trees have thin bark which offers little protection for the cambium (growing part of the tree), and the shallow roots are susceptible to soil heating. Seeds are usually killed by fire on the ground. Aspen are clones, with all the trees in one stand joined by underground roots; these roots can re-sprout quickly after a fire.
6. Unique factors: Ground fires will burn low-growing branches and rise up the tree to produce crown fires, which can kill a whole stand of trees. After a crown fire, aspen will quickly grow to dominate the area. Spruce seeds, carried by wind, become established under these aspen; spruce grow slowly but eventually will replace the aspen.

Fire Regimes

8

43. *Post-fire Survival of Bosque Trees*

Description: Students interpret real data from the Rio Grande bosque to determine the effects of fire on the growth and survival of different tree species.

Objective: Students will learn techniques to interpret data and will understand how different plant species are affected by fire (in other words, fire's positive and negative effects on ecosystems).

Materials: pencil, graph paper, markers or colored pencils, ruler, newspaper articles about bosque fires

Background: Many plant species occur in ecosystems adapted to fire, and these plants have a variety of adaptations to survive fires. Some trees have thick bark to protect living tissues inside, or may lack low branches to prevent fire from climbing into the canopy. Many herbaceous plants survive by producing seeds that are able to withstand the heat of fire, or may only sprout after a fire has passed over. Other plants can sprout from underground roots or from charred stumps that remain in the wake of a fire.

It is likely that fire was not an important part of the bosque ecosystem prior to the arrival of humans. Lightning strikes in adjacent uplands started fires that may have burned into the bosque, but these probably remained ground fires that swept quickly through grasses and forbs and did not greatly affect cottonwoods. In contrast, flooding and herbivory (eating by animals such as beavers) were more important in this ecosystem, and riparian plants are likely adapted to re-sprout after these disturbances, rather than after fire per se. The ability of cottonwoods and other native riparian shrubs and trees to sprout from trunks or roots after being knocked over

43. Post-fire Survival of Bosque Trees

Grades: 6–9

Time: one or two class periods

Subjects: math, biology, ecology

Terms: *fire intensity, fire severity, leaf litter, mortality, regeneration*

in a flood or being chewed by a beaver, however, does allow them to re-sprout after fires as well. Many of the exotic species now present in the bosque are also able to sprout after fires.

The mortality (death) of trees after a fire in the bosque depends on the severity of the fire. *Fire severity* is a measure of the degree to which a fire alters a given site and is used to estimate the *intensity* of the fire (intensity itself must be measured directly during the fire, based on heat production). Fire severity can be determined after a fire based on characteristics such as the extent of burn (char) on a tree or the amount of leaf litter remaining on the ground after the fire. A light-severity fire may damage trees, but they usually survive, while more severe fires will kill more trees. Often the above-ground portion of the plant dies (it may remain standing, fall over or even be completely consumed by the fire) but the plant is able to sprout from the base of the trunk or from underground roots. Typically sprouting occurs after light- to moderate-severity fires, while high-severity fires cause complete mortality. If post-fire conditions are right—enough moisture and not being eaten by browsing animals—the newly sprouted trees may survive after a light- to moderate-severity fire.

With the increasing impact of fire in the bosque, biologists have been studying the effects of fire on the survival of riparian plants. Here we will use data collected in the field to monitor the survival of cottonwood, saltcedar and Russian olive after two different fires in Albuquerque.

References:

Ellis, Lisa M. 2001. Short-term response of woody plants to fire in a Rio Grande riparian forest, Central New Mexico. Biological Conservation 97: 159-70

Stuever, Mary C. 1997. Fire Induced Mortality of Rio Grande Cottonwood. Master's thesis, University of New Mexico.

Procedure:

1. Access prior knowledge: Discuss the effects of fire on life in the bosque. Review definition of fire severity. Show "Before and After a Bosque Fire" photos included in this activity.
2. Divide into cooperative learning groups of two or three. Give each group a set of the student copy pages along with markers, graph paper and pencils. Follow directions on worksheets.
3. Once students have filled out their sheets, compare the results with the entire class.

Discussion Questions:

Teacher Key Part 1

1. *Bar graph*

2. What are some initial conclusions you can draw from these results?
   Cottonwood mortality is high, even in a light fire; mortality increases with fire severity.

3. What factors would cause a high-severity fire?
   Dry conditions; high winds; lots of dead and down wood/branches; deep, dry leaf litter.

4. Do you have any ideas as to why the rate of cottonwood mortality increased with the severity of the fire?
   Hotter fires burn more and kill more; if fire burned through the living tissue of the tree under the bark; fire burned living tissue on all sides of the trunk; tree lost too many of its leaves and small branches.

5. How might land managers (e.g. New Mexico State Forestry Division) use this information?
   Managers should reduce fuel build-up within the bosque, and fire fighters should work at keeping fire out of cottonwood areas.

Teacher Key Part 2

1. Calculate the percentage of trees with sprouts for each tree species.
   Saltcedar *89.6 percent*
   Cottonwood *81.1 percent*
   Russian olive *99.2 percent*

2. Which type of tree had the highest percentage of regeneration (sprouts)?
   Russian olive

3. Which type of tree had the lowest percentage of regeneration (sprouts)?
   Cottonwood

4. Create a graphic representation of this data.
   Answers will vary—bar graphs or pie charts will work.

5. Did native or exotic plants have higher survivorship?
   Exotic

6. What conclusions can you draw from this data?
   Even if the upper tree dies in a fire, some trees will sprout from their roots. Exotics are sprouting more than native plants.

Extensions: Look on the Internet for articles about bosque fires. What can you tell about the severity of fires described in news stories?

This U.S. Army Corps of Engineers web site has information about fires and restoration in the Rio Grande bosque: www.bosquerevive.com

Go on a field trip to a recent burn site and look at fire severity. Here are some things to look for:

- amount of leaf litter burned
- char on root collar (tree base)—Black all around? Burned through bark into wood? Are roots burned as well? Draw a circle to represent the tree base in cross-section and mark the portion that is scorched.
- trunk—highest scorch, highest scorch all around, if burned through bark into wood.
- crown—green today? Any visible scorching?
- number of trees sprouting from roots or trunk when above-ground portion is dead.

Post-fire Survival of Bosque Trees

Part 1

Fire severity is a measure of the degree to which a fire alters a given site. Fire severity can be determined after a fire based on characteristics such as the extent of burn (char) on a tree or the amount of leaf litter remaining on the ground, and is used to estimate the effects of fire intensity.

- **Light-severity fires had leaf litter that was burned in patches but not entirely consumed.**
- **Moderate-severity fires had most of the leaf litter consumed, although some patches of unburned material remained.**
- **High-severity areas had no remaining forest floor litter; these areas were often characterized by patches of white ash against black soil.**

Here are data describing mortality after three types of fires in the Albuquerque area.

	Fire Severity		
	Light	**Medium**	**High**
Cottonwood Mortality	**60%**	**75%**	**100%**

1. **Make a bar graph of these results on a separate page.**
2. **What are some initial conclusions you can draw from these results?**

3. **What factors would cause a high-severity fire?**

4. **Do you have any ideas as to why the rate of cottonwood mortality increased with the severity of the fire?**

5. **How might land managers (e.g., New Mexico State Forestry Division) use this information?**

Post-fire Survival of Bosque Trees

Part 2

The following data describe the survival of three different species of trees: native cottonwoods and exotic saltcedar and Russian olive. The above-ground portions of these trees were killed by the fire. These data show which trees sprouted from the roots within 90 days after the fire. Kim Lester and her Bosque School students collected these data following the Montaño Fire of June, 2003, on the west side of the Rio Grande.

Species	Total Trees	Trees w/ Sprouts	% w/ sprouts
Saltcedar	222	199	
Cottonwood	154	125	
Russian olive	250	248	

1. **Calculate the percentage of trees with sprouts for each tree species.**

2. **Which type of tree had the highest percentage of regeneration (sprouts)?**

3. **Which type of tree had the lowest percentage of regeneration (sprouts)?**

4. **Create a graphic representation of this data.**

5. **Did native or exotic plants have higher survivorship?**

6. **What conclusions can you draw from this data?**

Before and After a Bosque Fire

The Bosque del Apache National Wildlife Refuge near Socorro, NM, was lush and green in September 1992.

The same spot was photographed on June 20, 1996, shortly after the San Pedro fire.

Although above-ground tissues of cottonwoods were completely killed, tree roots were already sprouting on August 16, less than two months after the 1996 fire.

Growth was abundant on August 23, 1998, two years after the fire. Photos by Lisa Ellis.

44. Naturalist Notebooks: Fire

Description: Students learn how to keep notes on their observations and activities in the bosque while observing sites that have previously burned.

Objective: Students will develop essential observation and recording skills required of naturalists, scientists or other nature appreciators, in the context of studying the effects of fire in the bosque. They will notice what a fire does to a forest.

Materials: Naturalist Notebook: Fire activity pages
pencils
hard surface for writing, such as cardboard, notebook or a clipboard
thermometer
wind meter or Beaufort wind scale (included in this activity)
compass
wet/dry bulb thermometer (to determine relative humidity)
field guides for reference back in class

Background: This activity follows the format of the Naturalist Notebooks (Activity #4) in this guide. It provides a journaling activity focused on the topic of fire. This activity introduces students to the process of collecting field information and teaches them some basic journaling skills. This follows a similar format to the other Naturalist Notebook activities (introduction, general observations and site descriptions, directed observations and/or data collection and synthesis). This format encourages students to ask questions and continue their learning back in the classroom with field guides and other resources.

The focus in this activity is fire in the bosque. In addition to collecting basic types of data such as temperature and humidity, students make observations of plants and animals present in burned and unburned sites. Some burn sites are described in the essay "Fire in

44. Naturalist Notebooks: Fire

Grades: 5–12

Time: 30 minutes to one hour

Subjects: science, language arts, visual arts

Terms: *restoration, reclamation*

the Bosque" at the beginning of this chapter. This activity can stand alone, be used as an introduction to a study of fire in the bosque (including other activities in this chapter) or be part of a long-term journaling project. Please see the original Naturalist Notebooks, Activity #4, as well as Field Explorations Booklet, Activity #3, for more information on journaling.

Procedure: Make plans for a field trip to a bosque site that has burned and to nearby unburned areas. Some are listed in the "Fire in the Bosque" essay in this supplement; others may be found through an Internet search. It may be useful to do the Fire Vocabulary Match-Up, Activity #41, before doing this activity, to begin to familiarize students with some of the terms used to discuss fires. Use the following discussion points with students before the trip and while at the burned site.

Photocopy the Naturalist Notebook pages, one for each student.

Have students think about what they expect the burned site to be like, before you go. Make predictions about the physical characteristics of the burned and unburned areas (journal page 2, Compare and Contrast Burned and Unburned Sites). Do you expect there to be differences?

Can students tell if there was more than one fire on the same site?

Can students tell how long it has been since the fire? (Consider size of sprouts, amount of herbaceous growth, amount of decay in burned trees.) This may be affected by the type of restoration/reclamation activity that has occurred at the site, if any. In some cases, it may be difficult to tell that there has been a fire.

Discuss the difference between restoration and reclamation.

Extensions: Research Sir Francis Beaufort and the Beaufort Wind Scale on the Internet.

Keep a weather journal for your home or school.

Visit a recently burned site soon after a fire, and then visit it again at regular intervals to observe changes that occur as the site recovers from the fire.

Bosque Restoration

Land managers have different goals in treating natural sites that have been damaged, such as by a fire.

Restoration seeks to return a site to the way it was before modern humans altered it. *Reclamation* gives a new use to an area, which may not be similar to its original condition.

Can you see examples of restoration or reclamation at the burned site? Describe what you see.

Most fires in the bosque are started by people. What do you think about that? How do you think these fires are started?

Bosque Fire

Like most ecosystems, the bosque may have had fires, but the fires of the past were probably much cooler and less destructive. With the absence of regular flooding, forest conditions today are drier. Now there is a build-up of limbs, leaves and dead trees that provide fuel to make wildfires burn much hotter. Scientists are still learning about the long-term effects of fires in the bosque. Today you will make observations of burned and nearby unburned forest sites.

Name

Date and time

Location description

Weather (temperature, wind, cloud cover, precipitation in last 24 hours)

Fire Detective: Can you tell if there has been a fire at this site? Check off what you see:

- ☐ burned tree
- ☐ logs or stumps with charcoal on them
- ☐ several dead trees together
- ☐ sprouts of trees or shrubs from blackened stumps
- ☐ other (describe)

Compare Burned and Unburned Areas

Fire changes the physical and biological nature of a site, which provides a different habitat for organisms living there. Record the following data for the burned site and, for comparison, the nearby unburned forest. Record the following with thermometer, wet/dry bulb thermometer and Beaufort Wind Scale:

	Burned	Unburned
air temperature		
soil temperature		
humidity		
wind speed		

Simple observations can give information about biological factors. Record what you observe:

Leaf litter (Do leaves completely cover the ground or partially cover the ground, or are they absent?)

Burned

Unburned

Plants (Do you see grasses and low herbaceous plants, shrubs and/or trees growing? Can you identify any?)

Burned

Unburned

Wildlife (List or describe mammals, birds, reptiles, amphibians, insects or other invertebrates (or evidence of them).

Burned

Unburned

Spend a few minutes observing the burned site, and then the unburned site. Look up, down, all around. What is your impression? How does the burned site feel different from the unburned site? Can you tell what the burned site looked like before the fire? Write your thoughts and impressions here.

Find a piece of charcoal or a burned twig or piece of bark, and write or draw something with it here.

The Beaufort Wind Scale

The Beaufort Wind Scale is a system of recording wind velocity (speed) devised in 1806 by Francis Beaufort. It is a numerical scale ranging from 0 for calm to 12 for a hurricane. Sailors and forecasters use the Beaufort Wind Scale as a standardized way to rate wind speed.

Beaufort Scale	Wind Speed		Effects on Land	
	mph	kph		
0 (calm)	below 1	below 1		
1 (light air)	1–3	1–6	Smoke rises straight up; tree leaves still	
2 (light breeze)	4–7	7–12	Rising smoke drifts; wind felt on face	
3 (gentle breeze)	8–12	13–19	Leaves rustle; paper and dust raised	
4 (moderate breeze)	13–18	20–30	Small branches move; paper blows	
5 (fresh breeze)	19–24	31–39	Small trees sway, big branches move	
6 (strong breeze)	25–31	40–50	Big branches move; wind whistles	
7 (near gale)	32–38	51–62	Trees in motion; walking difficult	
8 (gale)	39–46	63–74	Twigs break; walking slow	
9 (strong gale)	47–54	75–87	Slight structural damage	
10 (storm)	55–63	88–102	Trees uprooted; structural damage	
11 (heavy storm)	64–72	103–117	Widespread damage	
12 (severe storm)	above 73	above 118	Severe damage and destruction	

45. Changing Fire

Description: By the roll of the dice, students use the "Changing River" model to see how fire reacts differently in the three variations of the river.

Objectives: Students learn about changes in the fire regime of the bosque that came about as the river and floodplain were altered, as well as changes with modern management approaches. In particular, students will learn that:

- there is now more fuel in the bosque, due to flood suppression and the introduction of exotic plants;
- there are now fewer fire breaks to stop large fires, since the mosaic of habitats in the floodplain has been lost;
- there are now more sources of ignition in the bosque, due to increased human activity;
- as a consequence of these factors, fires now are more frequent, burn hotter and burn a larger area than prior to the extensive changes to the floodplain; and
- new management strategies focus on removing the danger of catastrophic bosque fires.

Materials: the "Changing River" model, set up first as Rio Bravo, then Rio Manso and lastly Rio Nuevo

dice

"Changing Fire" component cards for Rio Bravo, Rio Manso and Rio Nuevo

Six flame cards for each river

(continued on next page)

45. Changing Fire

Grades: 5–12

Time: one hour when building on the already assembled Changing River activity (#13)

Subject: science

Terms: *exotic plants (introduced shrubs), fire break, fire intensity, fire regime, fire triangle, overbank flooding, thicket, understory*

22 yards (20.1 meters) of black yarn cut in the following lengths, at least twelve of each length:

Rio Bravo: 9 inches / 23 cm
Rio Manso: 38 inches / 97 cm
Rio Nuevo: 19 inches / 48 cm

Background: Unlike most upland ecosystems in the arid Southwest, fire probably was not a major factor influencing the bosque prior to European settlement. The bosque and floodplain evolved with flooding as a major source of disturbance, and flooding orchestrated the way different habitats were distributed across the floodplain. Prior to river regulation, the river moved across the floodplain, creating a patchwork of habitats, with marshes and wet meadows interspersed with forest stands of different ages—a patch of newly established seedlings along an attached sandbar, a stand of young trees farther up the bank, a stand of grand, mature trees with little understory a short distance downstream. When the snow melted from the mountains each year, high runoff inundated the forest, washing away some litter and dampening what was left, thereby increasing the rate of wood and leaf decomposition. Little litter, woody debris or understory shrubs remained, creating a park-like appearance.

Prior to the presence of humans in the Rio Grande Valley, the only source of ignition for fires was lightning. At the time of Rio Bravo, fires probably started from lightning strikes in the adjacent upland grasslands and burned down into the floodplain, but they would not have burned far into the floodplain due to moist conditions, a lack of fuel and the natural fire breaks. There simply were not long, dry, stick- and shrub-filled stretches of bosque to burn. Data from fire scars in annual growth rings of trees suggest that prehistoric fires occurred during the dry late-spring period, April through June, before summer thunderstorms arrived.

When the early Puebloans and first Spanish settlers arrived in the valley, they may have burned land to clear for crops, or burned uplands to promote grasses for livestock, and these fires may have burned into the bosque. However, the impact on the floodplain ecosystems still would have been minor, due to the factors described above. The biggest changes began in the early 1900s when the river was channelized and the frequency and extent of flooding decreased. These changes, with a now-stable river channel and lack of seasonal inundation, resulted in an increase in fuel in the forest as the dry conditions inhibited decomposition and fuels were no longer washed away by floods. Also at this time, exotic plants like saltcedar were introduced, and the whole structure of the forest

gradually changed. The patchy bosque stands interspersed with wetlands and meadows changed as wetlands dried up (due to ditches installed to lower the water table), meadows filled in with shrubs and trees and the forest became more continuous within the levees. The frequency of ignitions gradually increased with increasing human activity. In addition to lightning, the bosque now faces multiple sources of ignition: burning of adjacent fields or piles of brush to clear for agriculture, campfires, fireworks, cigarettes, children playing with matches and arson. These accidental (or intentional) fires spread quickly with the piles of dead wood and dry leaves present in the forest and the dense stands of flammable exotic plants such as saltcedar. The lack of fire breaks promotes their spread. The result is that for Rio Manso, fires burn hotter and cover much greater areas, with extensive cottonwood mortality. Since humans are now the main ignition source for bosque fires, fires now occur in every month of the year.

Fortunately, land managers are beginning to make changes to decrease the impact of fires in the bosque. Rio Nuevo results from a new vision of river and floodplain management, and one of the biggest changes is to decrease the standing fuel in the forest. Land managers are now removing much of the downed woody debris within the forest, as well as exotic shrubs and trees like saltcedar, elm and Russian olive and jetty jacks that impeded fire fighters' access. New wetlands are being created, and there is an attempt to restore the mosaic of floodplain habitats that once provided natural fire breaks. Man-made firebreaks are also being added, and in some places flooding is being reintroduced to the forest. All of these changes should help to decrease the impact of fire, by keeping fires more confined and of a lower intensity due to

Dead, charred trees stand along the Rio Grande after the 2003 Montaño fire, although the bankside willows have regrown. Photo by Mark B. Higgins.

reduced fuels. One important change is to decrease the frequency of ignitions, through public education and bosque closures. It is hoped that as more people learn of the vulnerability of the bosque to fires and become aware of the important role of humans as the sources of ignition, public stewardship will eliminate the need to close the bosque during dry periods with great fire threats. This is an important lesson for kids to learn—we really can make a difference!

Procedure: Introductory discussion:

What do you need for any fire to burn?

Heat, fuel, oxygen—called the fire triangle. All three are needed for a fire.

So, how do we put fires out?

Remove any one of the three parts of the fire triangle:

- Heat: cool fire with water from helicopter, hose, rain.
- Fuel: create fire break by removing vegetation down to mineral soil in zone around fire.
- Oxygen: snuff out and remove oxygen such as tossing dirt on a grass fire, cover flames with a heavy blanket, place a lid on burning food in a pot, use a candle snuffer on a candle flame.

Review with the class the river of the past, the human changes that have occurred and the improved management that is being implemented today. In this activity, you will see the differences in the effects of fire in the three systems: fire played a minor role in the bosque of Rio Bravo, before humans made many changes to the river ecosystem, but has had huge effects in the bosque of Rio Manso, when humans changed the flow of the river and subsequently the surrounding forest with dams, levees and introduced plant species. Finally, the role of fire may again be reduced in Rio Nuevo, with the removal of exotic plants, periodic over-bank flooding and reduced fuel build-up in the floodplain.

To start the activity, choose one item on the bosque model as an ignition point, such as one mature cottonwood tree. Students roll the dice to determine how the feature they selected on the model will be affected by fire. If there is a spread of fire for the number they landed on, they use the flame length for that river model to show the spread of fire. The flame is shortest for Rio Bravo (1.5 inches / 4 cm); longest for Rio Manso (6 inches / 15 cm), medium for Rio Nuevo (3 inches / 8 cm). Using the proper flame length as your radius, pivot the flame around the tree to see what other vegetation will be consumed by fire; any burnable object touched by the flames will burn. Use the appropriate length of yarn to encircle that area and show the extent of the fire. Students should remove plants from the burn area.

Math review of radius and circumferences is appropriate here. The longer pieces of yarn are the circumference of that particular flame-length radius. (See ***Extensions***.)

Have teams of students repeat the procedure for other items (e.g., meadow, sapling, etc.). Go around the class to have each group share what their item was and what happened during this fire season—what they did on the model during that round.

When finished with the Rio Bravo, you must replace items removed by fire and set up the model for Rio Manso. You should have the students do the main activity for Rio Nuevo—the restoration projects shown on the cards in Activity #13, Changing River—before looking at the effect of fire on the bosque of Rio Nuevo.

Discussion Questions

Describe the impact of fires in the Rio Manso. *(The narrow ribbon of bosque can be drastically reduced by a few fires.)*

Why are there more fires and more damage in the Rio Manso?

How has fire changed in each bosque?

Why are there different lengths of fire for each time of the river?

What would happen to the burned areas after a fire?

Discuss the effects of fire on each vegetation type (e.g., mature cottonwoods die out, saltcedar spreads, etc.) after each river round.

Discuss fire breaks. What makes a fire break? Did you know that a strong fire in heavy winds can jump the river?

How have the following changed in each part of the activity: amount of fuel, fire breaks, ignition sources?

How can management changes affect fire in the bosque?

How can we reduce fires in the bosque today?

How can your behavior affect fire in the bosque?

Notes: The fire area delineated may not be a circle, depending on the specific directions on the card. When there is little fire, and "fire does not spread," the yarn can be dropped in a small pile.

Rio Bravo will not need many pieces of yarn, as there were few fires.

You will have to replace certain pieces on the model for the activity to work. For example, there is only one cottonwood sapling and one grassy meadow on the model for the start of Rio Manso (Changing River Model Pieces: What to Have on the Model When, p. 165), so extra may have to be added. This is a model, and you must make adjustments along the way as needed.

For the purpose of this activity the "flame length" cards illustrate the combination of flame size plus the radiant heat from the fuel—the fire's intensity. These affect the fire's spread.

Each round of this activity is during the peak fire season, February through June of any given year.

Upland fires can spread into the bosque through strong winds.

If an area was recently burned, it is a "fire break." Fire will not burn there again.

There should be one card for every two or three students. You can duplicate the cards to accommodate a larger class. There are six cards for each stage (Rio Bravo, Manso and Nuevo). You can have one student in each group roll the dice and do what is on the card, then pass to the next student to roll the dice and follow directions for that number, and then the third student rolls the dice and follows the directions. Each student can choose a different place on the model to begin, such as a different mature cottonwood, for each roll of the dice.

Assessment: Oral or brief written assessment using Hansen's Comprehension Questions (from Freeman & Freeman, "Teaching Reading in a Multilingual Classrooms"):

1) What do you remember?

2) What else would you like to know?

3) What does it remind you of?

4) What other things have you read that it reminds you of?

Pre-teach the model cards before playing (what do students know before?)

Review before resuming play (what do students remember?)

Review after play (what did students learn?)

Place a frame to isolate parts of the activity while in play. Ask groups to describe what is happening in that section.

Extensions: Pre-teach a math component of radius, diameter and circumference. Give students the radius of flame spread for each time period on the river and have them calculate the circumference of yarn needed.

Rio Bravo radius = 1.5 inches (4 cm); circumference = 9 inches (23 cm)

Rio Manso radius = 6 inches (15 cm); circumference = 38 inches (97 cm)

Rio Nuevo radius = 3 inches (8 cm); circumference = 19 inches (48 cm)

The burned areas on the model can be indicated by mapping: students can draw the growing burned area on graph paper to create an area map. These can become story indicators for setting up the activity if disturbed or keeping track of progress of activity during recess or a weekend, etc.

Use clear plastic bags and a wall chart to insert and sort plants burned in the course of the activity; then graph the numbers to compare each river model.

Simplifying the activity for K-5

Reduce the number of plant pieces by half to reduce visible clutter.

Use repetition and repetitive patterns to support reading in this activity.

Cut out and sort model pieces and label bags.

Place pieces on the model in the proper locations.

Teach the names associated with different model pieces: associate the symbol with living plant on a field trip activity

Use cumulative patterns. For example: How many mature cottonwood trees do we have? How many do we need to play this activity? How many cottonwood saplings were burned?

Create a chart of burned and removed plants (math component).

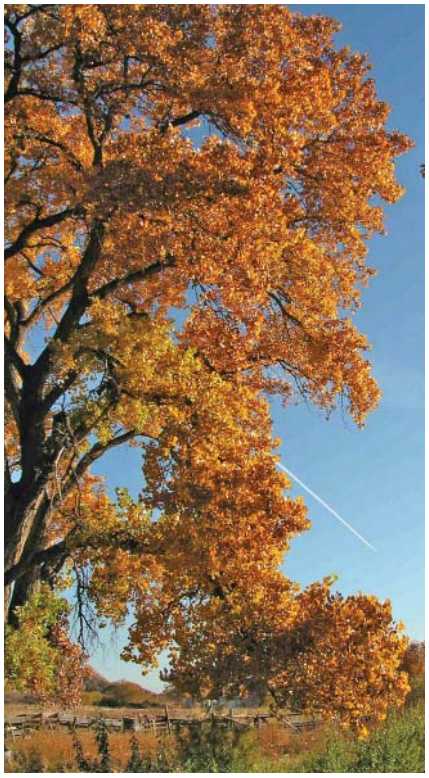
Have students think up alliterations about the activity such as, "How much wood would a woodchuck chuck, if a woodchuck could chuck wood?" Or something using rhythm such as a chant indicated by S-shaped movement using hands mimicking the directional flow of the water (change tenses to indicate time).

"…and the Rio Bravo flowed on and on…"

"…and the Rio Manso flows on and on…"

"…and the Rio Nuevo will flow on and on…"

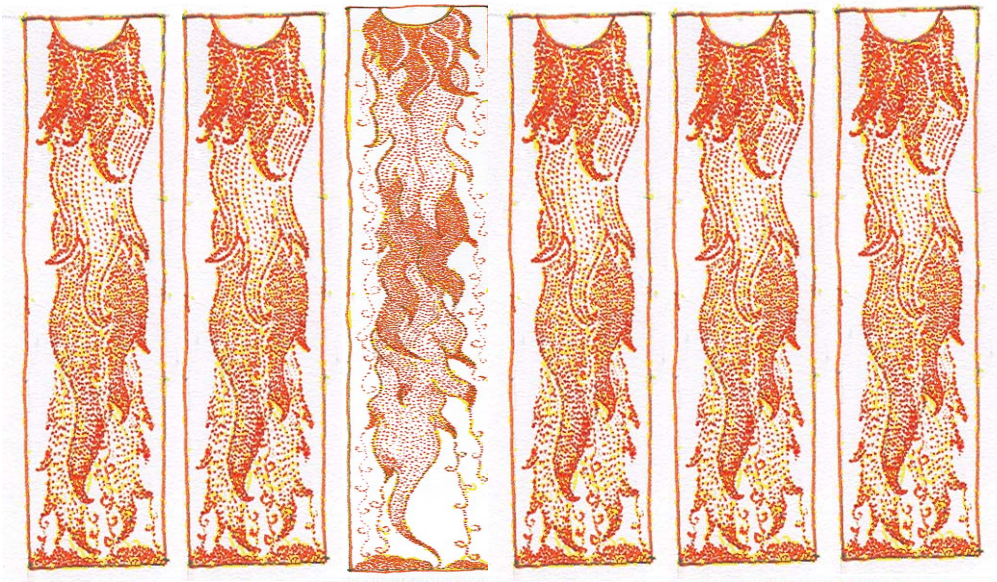
Think of rhymes.



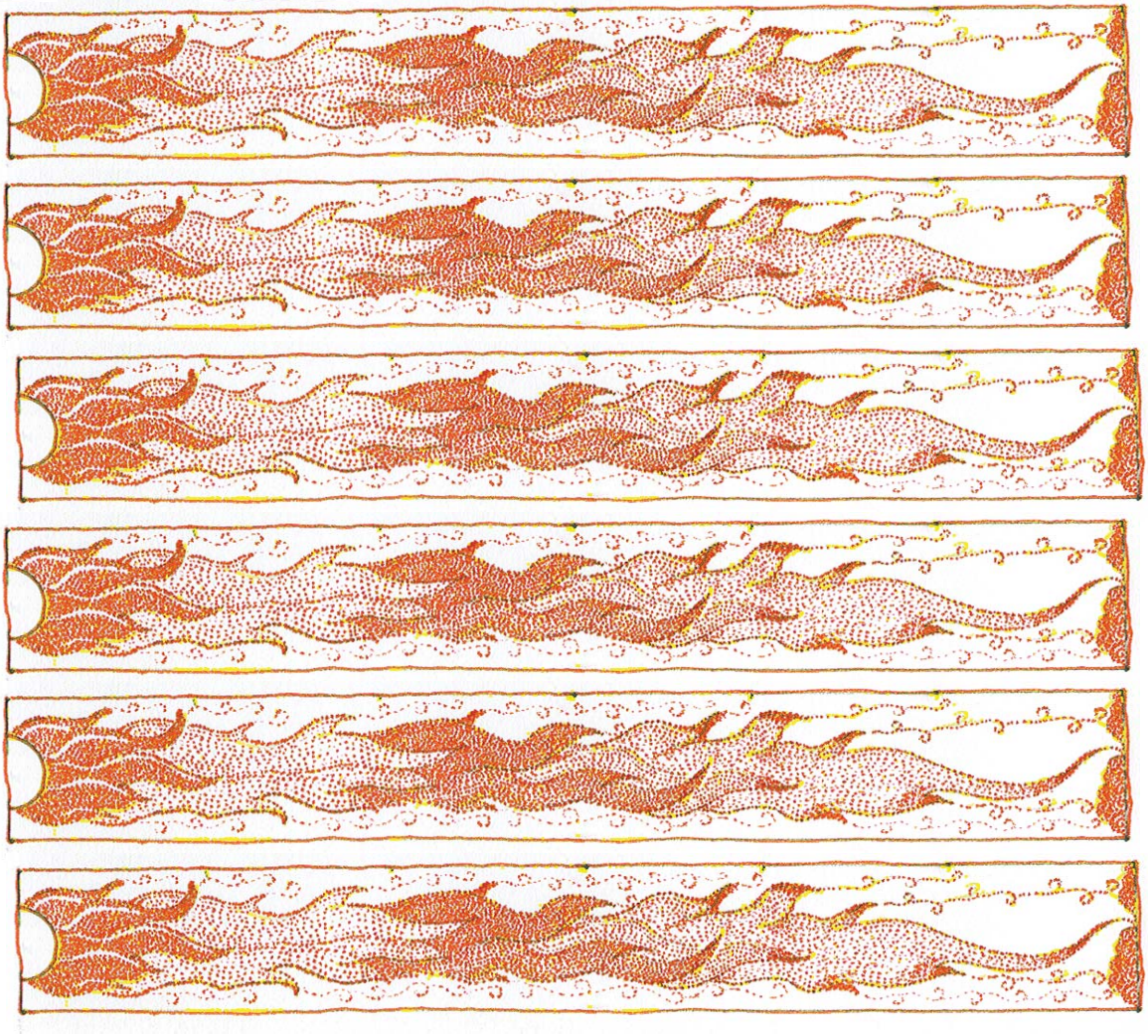
Fall cottonwood near Algodones. Photo by Mark B. Higgins.

Flame Lengths for Rio Grande Fires

→ *Rio Bravo*



← *Rio Nuevo*



→ *Rio Manso*

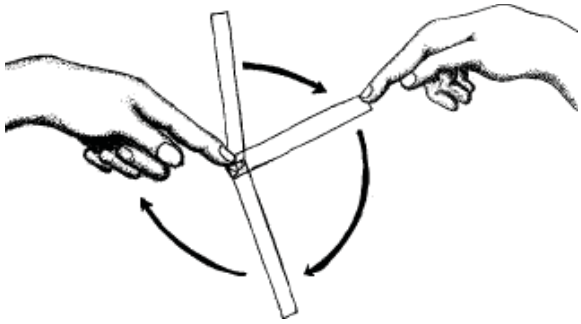
Changing Fire Model Directions

1. **Pick one item on the model for this turn. For example, if you have the "Shrub thicket" card, pick one shrub on the model as the focus for this round.**
2. **Roll the dice and follow the directions for that number on your card.**
3. **If that number has a "fire spread" use the flame length card for that model of the river:**

   Rio Bravo = 1.5 inches/4 cm

   Rio Manso = 6 inches/15 cm

   Rio Nuevo = 3 inches/8 cm



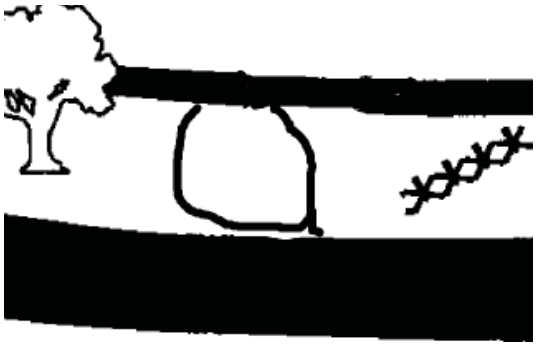
As in this illustration, place the center of the flame on your item, the "shrub thicket" you have identified in #1 above.

- √ **Pivot the flame around.**
- √ **Then circle that area with black yarn of the proper length:**

  Rio Bravo = 9 inches/23 cm

  Rio Manso = 38 inches/97 cm

  Rio Nuevo = 19 inches/48 cm



4. **Remove all plants within the circle.**

   Leave yarn to show where the fire burned.

   Remove the flame card.
5. **If the card instructs a small fire, use the yarn dropped onto that plant or few plants, to indicate what burned.**

Changing Fire: Rio Bravo

I am a… **Mature Cottonwood Tree**

Roll the dice. Follow directions for the number it lands on. Example: If you roll the number 2, then follow the directions for item 2 in the list below. There is a greater chance for some things to happen, so some options are listed more than once. Use your imagination and the model pieces to demonstrate any changes.

1. There is no source of ignition, so there is no fire.
2. Lightning strikes the tree. It leaves a scar, but the fire does not spread. The forest is flooded by spring runoff.
3. It is raining. There is no source of ignition, so there is no fire.
4. Fire starts in the grassland/uplands. The fire spreads to the edge of the floodplain where it stops at a clearing. The tree is not burned.
5. There is no source of ignition, so there is no fire.
6. Lightning strikes the tree. It leaves a scar, but the tree continues growing.

Changing Fire: Rio Bravo

I am a… **Cottonwood Sapling**

Roll the dice. Follow directions for the number it lands on. Example: If you roll the number 2, then follow the directions for item 2 in the list below. There is a greater chance for some things to happen, so some options are listed more than once. Use your imagination and the model pieces to demonstrate any changes.

1. It is raining. There is no source of ignition, so there is no fire.
2. Lightning strikes the sapling. The fire spreads to the edge of a clearing and stops.
3. Lightning strikes the sapling. There is little dry fuel. The fire burns only a small area.
4. Forest is flooded by spring runoff. There is no fire.
5. There is no source of ignition, so there is no fire.
6. Lightning strikes the sapling. The bosque is flooded so only a small area burns.

Changing Fire: Rio Bravo

I am a…**Marsh/Wetland**

Roll the dice. Follow directions for the number it lands on. Example: If you roll the number 2, then follow the directions for item 2 in the list below. There is a greater chance for some things to happen, so some options are listed more than once. Use your imagination and the model pieces to demonstrate any changes.

1. There is no source of ignition, so there is no fire.
2. Lightning strikes the grassy uplands. Fire spreads to the edge of the marsh where it stops.
3. It is raining. There is no source of ignition, so there is no fire.
4. Lightning strikes a nearby tree. Fire burns to the edge of the marsh and stops.
5. Lightning strikes the edge of the marsh. The marsh is wet so there is no fire.
6. It has been a wet spring. The marsh is unaffected by fire.

Changing Fire: Rio Bravo

I am a…**Grassy Meadow**

Roll the dice. Follow directions for the number it lands on. Example: If you roll the number 2, then follow the directions for item 2 in the list below. There is a greater chance for some things to happen, so some options are listed more than once. Use your imagination and the model pieces to demonstrate any changes.

1. There is a drought. Lightning strikes a grassy meadow. The grass is dry and the fire spreads.
2. There is no source of ignition, so there is no fire.
3. Lightning strikes a grassy meadow. The meadow is flooded so there is no fire.
4. There is no source of ignition, so there is no fire.
5. Lightning strikes a grassy meadow. The meadow is flooded so there is no fire.
6. There is no source of ignition, so there is no fire.

Changing Fire: Rio Bravo

I am an…**Upland Shrub**

Roll the dice. Follow directions for the number it lands on. Example: If you roll the number 2, then follow the directions for item 2 in the list below. There is a greater chance for some things to happen, so some options are listed more than once. Use your imagination and the model pieces to demonstrate any changes.

1. There is a light spring rain. There is no source of ignition, so there is no fire.
2. Strong winds dry the shrubs. There is no source of ignition, so there is no fire.
3. Lightning strikes the upland shrub, but it is raining, so there is no fire.
4. Lightning ignites a dry shrub. Strong winds spread fire to nearby grasses.
5. Lightning starts a fire in the shrub. It moves toward the floodplain. Moist soil from recent flooding stops the fire.
6. There is no source of ignition, so there is no fire.

Changing Fire: Rio Bravo

I am a…**Shrub Thicket** (“native riparian shrub” such as willow)

Roll the dice. Follow directions for the number it lands on. Example: If you roll the number 2, then follow the directions for item 2 in the list below. There is a greater chance for some things to happen, so some options are listed more than once. Use your imagination and the model pieces to demonstrate any changes.

1. There is no source of ignition, so there is no fire.
2. Lightning strikes a willow thicket at the edge of the river. The willow burns, but flames die out as they reach a wetland.
3. The bosque is moist from flooding. There is no source of ignition, so there is no fire.
4. There is a drought. Lightning strikes a willow thicket and spreads.
5. The bosque floor is moist from flooding. There is no source of ignition, so there is no fire.
6. Lightning strikes a stand of small shrubs and spreads. The fire dies out when it reaches a clearing.

Changing Fire: Rio Manso

I am a…**Mature Cottonwood Tree**

Roll the dice. Follow directions for the number it lands on. Example: If you roll the number 2, then follow the directions for item 2 in the list below. There is a greater chance for some things to happen, so some options are listed more than once. Use your imagination and the model pieces to demonstrate any changes.

1. There is a drought. Lightning starts a fire in the tree and it spreads.
2. A campfire left unattended spreads through the dry leaves and ignites the tree. High winds spread the fire quickly.
3. Lightning strikes the tree and starts a fire. The heavy undergrowth and downed branches catch fire. The fire spreads.
4. Carelessly tossed fireworks start a fire in dry leaves and plants under the tree. Strong winds quickly spread the fire.
5. Lightning strikes the tree. It leaves a scar, but the fire does not spread.
6. A tossed cigarette smolders in leaves under a tree. Flames spring up and spread.

Changing Fire: Rio Manso

I am a…**Cottonwood Sapling**

Roll the dice. Follow directions for the number it lands on. Example: If you roll the number 2, then follow the directions for item 2 in the list below. There is a greater chance for some things to happen, so some options are listed more than once. Use your imagination and the model pieces to demonstrate any changes.

1. There is a drought. Lightning starts a fire in the sapling and the fire begins to spread.
2. A campfire left unattended spreads through the dry leaves and ignites a sapling. High winds fan the flames, and the fire spreads.
3. Lightning strikes. A fire starts in the sapling. The heavy undergrowth and downed branches nearby are fuel for a hot fire, which spreads quickly.
4. Carelessly tossed fireworks start a fire under the sapling. Strong winds spread the fire quickly.
5. Lightning strikes the area. It has been raining. There is no fire.
6. A tossed cigarette smolders under the sapling. Flames spring up and spread.

Changing Fire: Rio Manso

I am a…**Marsh/Wetland**

Roll the dice. Follow directions for the number it lands on. Example: If you roll the number 2, then follow the directions for item 2 in the list below. There is a greater chance for some things to happen, so some options are listed more than once. Use your imagination and the model pieces to demonstrate any changes.

1. There is a drought. Lightning starts a fire in the dry marsh. The fire spreads.
2. A campfire is left unattended. High winds carry sparks to leaves. Parts of the marsh burn.
3. Lightning strikes a meadow near the marsh. A fire starts. Some of the marsh plants burn.
4. Carelessly tossed fireworks start a fire. Gusty winds spread the fire.
5. Lightning strikes the area. It has been raining so only the edge of the marsh burns.
6. A tossed cigarette starts a fire in the dry marsh. The fire spreads to nearby grasses.

Changing Fire: Rio Manso

I am a…**Grassy Meadow**

Roll the dice. Follow directions for the number it lands on. Example: If you roll the number 2, then follow the directions for item 2 in the list below. There is a greater chance for some things to happen, so some options are listed more than once. Use your imagination and the model pieces to demonstrate any changes.

1. A tossed cigarette ignites grass in the meadow. The fire spreads.
2. Someone builds a campfire. Sparks ignite nearby grass. The fire spreads.
3. Lightning strikes the meadow. Dry grass and leaves burn, and the fire spreads.
4. Lightning strikes dead branches near the meadow. Fire spreads across the meadow and beyond.
5. Kids are playing with fireworks in the bosque. Sparks ignite the dry grass and the fire spreads.
6. Lightning strikes the meadow. A fire starts and spreads through the grass.

Changing Fire: Rio Manso

I am an…**Upland Shrub**

Roll the dice. Follow directions for the number it lands on. Example: If you roll the number 2, then follow the directions for item 2 in the list below. There is a greater chance for some things to happen, so some options are listed more than once. Use your imagination and the model pieces to demonstrate any changes.

1. A cigarette is tossed from a car. Dry roadside grass and shrubs ignite. Wind spreads the flames toward the bosque.
2. Someone builds a campfire. Wind spreads sparks into a stand of upland shrubs.
3. Lightning strikes an upland shrub. A fire starts and spreads through dry grass.
4. Kids are playing with matches and accidentally start a fire. Flames spread to shrubs.
5. Lightning strikes upland shrubs. The fire spreads through dry grass and into the bosque.
6. Lightning strikes an upland shrub. It is too wet to spread.

Changing Fire: Rio Manso

I am a…**Shrub Thicket** (“introduced shrubs” such as saltcedar)

Roll the dice. Follow directions for the number it lands on. Example: If you roll the number 2, then follow the directions for item 2 in the list below. There is a greater chance for some things to happen, so some options are listed more than once. Use your imagination and the model pieces to demonstrate any changes.

1. A person smoking in the bosque drops a lit cigarette. Dry leaves begin to burn and ignite dead branches. The fire spreads.
2. Someone builds a campfire. Sparks escape into a saltcedar thicket. The fire spreads.
3. Lightning strikes the shrub thicket. It sparks a fire in dry leaves, and spreads.
4. Lightning strikes the shrub thicket. The fire grows with lots of fuel and spreads.
5. Kids light fireworks in the bosque. Dry weeds catch fire and the fire spreads through the shrub thicket.
6. Lightning strikes the shrub thicket. It starts a fire in dry undergrowth. The fire spreads.

Changing Fire: Rio Nuevo

I am a…**Mature Cottonwood Tree**

Roll the dice. Follow directions for the number it lands on. Example: If you roll the number 2, then follow the directions for item 2 in the list below. There is a greater chance for some things to happen, so some options are listed more than once. Use your imagination and the model pieces to demonstrate any changes.

1. There is a drought. Lightning starts a fire in a cottonwood tree. Exotic saltcedar has been removed from this area. Only two cottonwood trees burn and the fire dies out.
2. A campfire left unattended spreads through dry leaves. Downed wood has been removed so. the fire remains a ground fire only.
3. Lightning strikes the tree and starts a fire. Undergrowth and downed branches have been removed and the bosque is flooded. Only one cottonwood tree dies.
4. Fireworks are carelessly tossed near the tree. Dry leaves and wood spread the fire.
5. Lightning strikes the tree. The bosque is flooded. The fire does not spread, but it leaves a scar.
6. A carelessly tossed cigarette starts a fire under the tree. The area has not yet been cleared of downed wood. The fire spreads.

Changing Fire: Rio Nuevo

I am a…**Cottonwood Sapling**

Roll the dice. Follow directions for the number it lands on. Example: If you roll the number 2, then follow the directions for item 2 in the list below. There is a greater chance for some things to happen, so some options are listed more than once. Use your imagination and the model pieces to demonstrate any changes.

1. There is a drought. Lightning starts a fire in the sapling. Undergrowth and downed branches have been removed. Two cottonwood saplings die but the fire burns out.
2. A campfire left unattended spreads through leaves on the ground. Downed wood has been removed so the fire remains a ground fire.
3. Lightning strikes the sapling. Fire starts. Water covers the floodplain. The fire does not spread.
4. Fireworks are carelessly tossed in dry leaves near the sapling, which starts burning. The bosque is flooded so only one tree burns.
5. Lightning strikes the sapling. The sapling starts burning and a fire spreads.
6. A carelessly tossed cigarette smolders in dry leaves near the sapling. The area has not been cleared of downed wood. The fire spreads.

Changing Fire: Rio Nuevo

I am a…**Marsh/Wetland**

Roll the dice. Follow directions for the number it lands on. Example: If you roll the number 2, then follow the directions for item 2 in the list below. There is a greater chance for some things to happen, so some options are listed more than once. Use your imagination and the model pieces to demonstrate any changes.

1. There is a drought. Lightning starts a fire in the dry marsh. The fire spreads.
2. A campfire is left unattended in a nearby forest. Fire spreads through leaves on the ground. A constructed wetland serves as a fire break; the fire stops.
3. Lightning strikes the marsh. A fire burns a few of the marsh plants but then burns out.
4. Fireworks start a fire in a meadow. Gusty winds spread it to the edge of the marsh, whichacts like a fire break and the fire stops.
5. Lightning strikes nearby shrubs. Fire burns to the edge of the newly constructed wetland and stops.
6. A tossed cigarette smolders. The marsh is wet and the fire does not spread.

Changing Fire: Rio Nuevo

I am a…**Grassy Meadow**

Roll the dice. Follow directions for the number it lands on. Example: If you roll the number 2, then follow the directions for item 2 in the list below. There is a greater chance for some things to happen, so some options are listed more than once. Use your imagination and the model pieces to demonstrate any changes.

1. A cigarette is tossed into a grassy meadow. The dry grass burns. Flames die out at a fire break.
2. Someone leaves a fire unattended. The fire spreads through the grass and into the bosque.
3. Lightning strikes the grassy meadow. A small fire burns, but goes out where ground fuel has been removed.
4. Lightning strikes a grassy meadow and starts a fire. The flames die since the grass is wet from overbank flooding.
5. Kids toss fireworks into the meadow. A fire starts and travels toward the river bank.
6. Lightning strikes a grassy meadow. The grass and soil are wet from a recent overbank flood. There is no fire.

Changing Fire: Rio Nuevo

I am an…**Upland Shrub**

Roll the dice. Follow directions for the number it lands on. Example: If you roll the number 2, then follow the directions for item 2 in the list below. There is a greater chance for some things to happen, so some options are listed more than once. Use your imagination and the model pieces to demonstrate any changes.

1. A cigarette is tossed from a car. It ignites a shrub and the fire spreads.
2. Lightning strikes an upland shrub. There is little fuel nearby. The fire does not spread.
3. Kids lighting fireworks start a fire that travels toward the bosque. A flood has wet the bosque. The fire dies out.
4. Lightning strikes an upland shrub. A fire starts and spreads.
5. Lightning strikes an upland shrub. A fire starts and moves toward the bosque. Cleared ground stops the fire.
6. Someone builds a fire. Sparks ignite an upland shrub. One shrub burns.

Changing Fire: Rio Nuevo

I am a…**Shrub Thicket** (such as willows)

Roll the dice. Follow directions for the number it lands on. Example: If you roll the number 2, then follow the directions for item 2 in the list below. There is a greater chance for some things to happen, so some options are listed more than once. Use your imagination and the model pieces to demonstrate any changes.

1. Lightning strikes the shrub thicket. The ground is wet from flooding. There is no fire.
2. Someone builds a campfire near some shrubs. Wind carries sparks into the shrubs. This area has not been cleared of saltcedar; fire spreads quickly.
3. Lightning strikes a shrub. It has been raining. The shrub smolders, but no fire starts.
4. Fireworks ignite dead leaves under a shrub. The site has been cleared of downed wood, so there is little fuel for the fire to spread. The fire burns out.
5. Lightning strikes the shrub thicket. The ground is wet from flooding. There is no fire.
6. Someone tosses a cigarette in the shrub thicket. A shrub smolders and bursts into flame. The fire spreads.