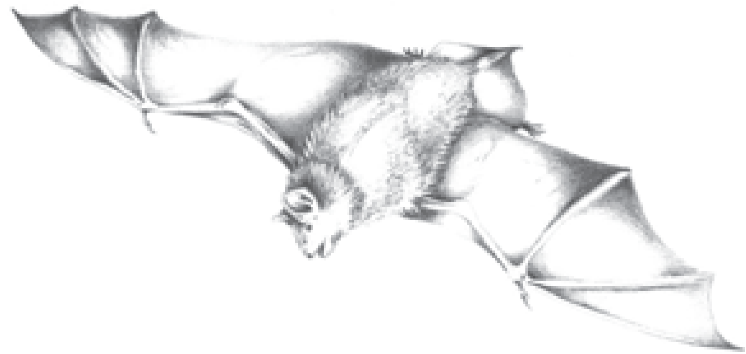


Chapter 4

River of Change:
River Model Activities

Updated June 2020

Funded by New Mexico Game & Fish *Share with Wildlife*

A Model of the Middle Rio Grande Valley

Rio Bravo, Rio Manso, Rio Nuevo—A Tale of Three Rivers

Introduction

It is the nature of rivers to change. As described in Chapter 2, Bosque Background, until the past century most of the dramatic changes along the Middle Rio Grande occurred through a natural flooding cycle. The river valley was a changing mosaic of habitats: over the years marshes would form, silt in, and dry out; riverbanks would develop and then shift locations; cottonwood trees would sprout and then some would be washed away while other stands would grow to maturity. Although these changes were sometimes dramatic, they were generally cyclical. If a single stand of trees was washed away, somewhere in the valley other stands were getting established. When a marsh dried out and became grassland, other marshes were being formed elsewhere that provided wet habitat.

Human activity has disrupted this annual flooding cycle, particularly in the past century. To control flooding and dry out waterlogged soils in the valley, people built dams, reservoirs, levees and drains. In addition, people have intentionally and accidentally introduced many exotic plants and animals to the area. Major components of the bosque, such as water table levels and plant and animal communities, are rapidly changing. Instead of occurring in a circular pattern, with all habitats present in the valley, this kind of change follows a linear pattern. As a response to differences in available water, new communities of plants and animals are replacing some habitats that had existed in this valley for hundreds of thousands of years.

Humans also impact the bosque in many positive ways. Particularly since 1993, many projects in the bosque have been focused on restoring the ecological sustainability of this ecosystem.

In order to treat our river wisely, we must understand the role of change in the river ecosystem. We need to be able to recognize what kinds of changes are healthy for our bosque, and what kinds of changes may permanently affect our bosque and the plants and animals that live there.

The hands-on activities in this chapter help students learn about some of the changes, both natural and human-influenced, that our river has faced and will continue to face. The core of these activities is a model consisting of a large cloth (blanket-sized), paper cutouts and material strips. Models are tools that help us simplify complex systems so we can understand various components of those systems more clearly. This model illustrates the Rio Grande in three different stages, depending on the kind of changes the river is experiencing.

We are calling these stages **Rio Bravo** (the wild river), **Rio Manso** (the tame river) and **Rio Nuevo** (the new river). By constructing the images of these rivers, students will grasp some of the differences between the historical and the present-day systems and understand some of the challenges we face in managing our new river.

Rio Bravo is the old river, the prehistoric river that was not strongly influenced by human activity. This river experienced an annual flooding cycle, although the intensity of these floods varied from year to year. We can speculate about many features of Rio Bravo, but this river no longer exists. It is important to understand what it was like in order to preserve some of its features in managing today's river.

Modern communities along the Rio Grande had trouble living harmoniously with the wild river. Homes, farms and businesses were regularly flooded. Farmers needed water to be available throughout the growing season, not just in one major flood early in the summer. Many projects were developed to harness the Rio Grande to fit human needs. Dams were built so that spring runoff could be stored in reservoirs and made available to farmers throughout the summer. Levees and jetty jacks were constructed to prevent the river from meandering and flooding communities. Rather than allow the river to move around on the valley floor, human settlement dictated that the river stay in a designated location. In the Middle Rio Grande Valley, a large cottonwood-dominated forest developed between the levees and the river. On the model, we call this river **Rio Manso**. Like a horse that has been tamed for riding, this river now serves the people who live within the valley.

The changes that created this tame river, that allow our communities to live and thrive in the Middle Rio Grande Valley, do not always provide the optimal conditions for the native plants and animals that evolved in the valley under the conditions of the old river. Some species that lived in and around the old river are now extinct, and several more species are endangered. To manage the river for all organisms—human needs and the needs of plant and animal species—we must find a way to incorporate the features of both Rio Bravo and Rio Manso into a river system that supports a diversity of life. In this model we call that **Rio Nuevo**, or the new river. This is the river of our future, and with each thoughtful action we come closer to meeting these goals.

"Changing River," the core activity, is simply the process of laying out the model and making the transitions between Rio Bravo, Rio Manso and Rio Nuevo. Although this may be a time-consuming activity the first time, students quickly acclimate to this task and will soon be able to set up each of these scenarios in a matter of minutes.

The rest of the activities are based on the "Changing River" activity. Recognizing that the time constraints of each class will vary, there is flexibility in these modeling exercises. Not every class will be able to participate in every activity, and there is no specific order for introducing the remaining activities. In practice we have found that these remaining activities work well alone in separate sessions or combined together. These two approaches for using this chapter are outlined on the next two pages.

"Cottonwood Creation" helps students understand how cottonwoods are established and why cottonwood trees in the valley are declining. This two-step activity includes a germination step, where students toss cotton balls and determine which locations are likely to allow seeds to germinate, and the "Root Race" when the young seedlings are trying to survive their first season by reaching their roots to the groundwater table.

"Who Lives Where?" builds the students' understanding of the animal life in the bosque and river. Students read about an animal's characteristics and place a picture of the animal on the model in the appropriate habitat. In this edition of the *Guide*, there are two sets of animal cards for different levels of readers. Some cards have also been added for classes focusing on upper watersheds north of Cochiti Lake.

"Who Grows Where?" is similar to the animal game, but with plant cards instead.

"Working Water" takes an in-depth look at the agricultural systems of water management and how these support agriculture as well as wildlife.

"Bosque Chaos" is a game that uses dice to help students see the role of change and chaos in annual flooding patterns in Rio Bravo, then compare the linear types of changes in Rio Manso and a combination of cyclical and linear changes in Rio Nuevo.

The most important concept is for students to create a visual picture of the differences between Rio Bravo, Rio Manso, and Rio Nuevo. Students should be able to contrast the river of the past with the river of today, and then to also contrast today's river when it is managed for human development with today's river when it is managed for the whole ecosystem. By creating models of these three stages of the Rio Grande, the powerful teaching technique of contrast is used to clarify the role humans have played and can play in this river ecosystem.

Science Standards

These activities are now correlated with New Mexico STEM Ready! Science Standards, including both the national Next Generation Science Standards (NGSS) and New Mexico-specific standards. References to standards are included in a box at the beginning of each activity for quick reference, in the text of each activity, in more detail at the end of each activity and in **Appendix K**. By completing the full River of Change unit, your students will address many of the science standards, as well as many Common Core/ELA standards. We encourage you to use these resources as you explore the *Guide* with your students. See Appendix K for an overview of the standards addressed by these activities and for detail on middle school standards.

River of Change: Two Approaches

1. The "Separate Activities" Approach

Each time the model is used, one activity in the chapter is presented.

First Day: Introduction to the Three Rivers Modeling Concept

Changing River Section A: Rio Bravo	⇨	Changing River Section B: Rio Manso	⇨	Changing River Section C: Rio Nuevo

Second Day: Learning About Cottonwood Tree Biology

Cottonwood Creation Part 1: Cotton Game Section A: Rio Bravo Part 2: Root Race Section A: Rio Bravo	⇨	Cottonwood Creation Part 1: Cotton Game Section B: Rio Manso Part 2: Root Race Section B: Rio Manso	⇨	Cottonwood Creation Part 1: Cotton Game Section C: Rio Nuevo Part 2: Root Race Section C: Rio Nuevo

Third Day: Learning About Animals in the Bosque

Who Lives Where? Section A: Rio Bravo	⇨	Who Lives Where? Section B: Rio Manso	⇨	Who Lives Where? Section C: Rio Nuevo

Fourth Day: Learning About Plants in the Bosque

Who Grows Where? Section A: Rio Bravo	⇨	Who Grows Where? Section B: Rio Manso	⇨	Who Grows Where? Section C: Rio Nuevo

Fifth Day: Understanding More About Irrigation in the Middle Rio Grande Valley

Working Water Rio Manso

Sixth Day: Understanding the Role of Change in the Bosque

Bosque Chaos Section A: Rio Bravo	⇨	Bosque Chaos Section B: Rio Manso	⇨	Bosque Chaos Section C: Rio Nuevo

Seventh Day: Understanding the Role of Fire in the Bosque.

Changing Fire Section A: Rio Bravo	⇨	Changing Fire Section B: Rio Manso	⇨	Changing Fire Section C: Rio Nuevo

2. The "Building on Each River" Approach

In this approach, students work through all of the activities for each phase of the river model before moving on to the next phase.

First 2–3 Days: **Rio Bravo**	**Next 2–3 Days:** **Rio Manso**	**Final Day:** **Rio Nuevo**
Changing River Section A: Rio Bravo	*Changing River* Section B: Rio Manso	*Changing River* Section C: Rio Nuevo
⇩	⇩	⇩
Cottonwood Creation Part 1: Cotton Game Section A: Rio Bravo Part 2: Root Race Section A: Rio Bravo	*Cottonwood Creation* Part 1: Cotton Game Section B: Rio Manso Part 2: Root Race Section B: Rio Manso	*Cottonwood Creation* Part 1: Cotton Game Section C: Rio Nuevo Part 2: Root Race Section C: Rio Nuevo
⇩	⇩	⇩
Who Lives Where? Section A: Rio Bravo	*Who Lives Where?* Section B: Rio Manso	*Who Lives Where?* Section C: Rio Nuevo
⇩	⇩	⇩
Who Grows Where? Section A: Rio Bravo	*Who Grows Where?* Section B: Rio Manso	*Who Grows Where?* Section C: Rio Nuevo
⇩	⇩	⇩
	Working Water Rio Manso	
⇩	⇩	⇩
Bosque Chaos Section A: Rio Bravo	*Bosque Chaos* Section B: Rio Manso	*Bosque Chaos* Section C: Rio Nuevo
⇩	⇩	⇩
Changing Fire Section A: Rio Bravo	*Changing Fire* Section B: Rio Manso	*Changing Fire* Section C: Rio Nuevo

Bulldozers in the Bosque

Hey, they're bulldozing the bosque! How can that be restoration?

In recent years resource managers have been using these big machines with a new goal in mind. Instead of bulldozing the forest to clear it for human use, 'dozers are now being used to help restore the forest. In what managers and scientists like to call "bulldozer ecology," heavy equipment is being used to clear out exotic vegetation and alter the riverbank to allow flooding. One successful example of this is the Albuquerque Overbank Project.

The Albuquerque Overbank Project (AOP) is a collaborative effort with participants from the U.S. Bureau of Reclamation, University of New Mexico Department of Biology, City of Albuquerque Open Space Division, Middle Rio Grande Conservancy District, New Mexico Natural Heritage Program, U.S. Fish and Wildlife Service, State of New Mexico Environment Department and U.S. Army Corps of Engineers. The AOP site is located on the southern end of an elevated, attached river bar on the west side of the Rio Grande, north of Rio Bravo. Because of riverbed degradation, it had received little if any overbank flooding in recent decades. This project was designed to evaluate the effectiveness of bank clearing and lowering to reestablish native woody vegetation (cottonwoods and willows) on such a site in the Albuquerque Reach of the Middle Rio Grande bosque.

Site preparation, using bulldozers and other heavy equipment, began in March 1998. It involved clearing and root plowing 4 acres (1.6 ha) of the bar's dense Russian olive cover, then lowering over half of the cleared area by 2 feet (0.6 m) to allow for flooding during spring runoff events and summer wet periods. Trees that were cleared were removed and chipped. Material from the bank was spread over a connected (lower) sandbar south of the cleared site. Shallow channels and topographic undulations were created on the cleared bar to facilitate floodwater distribution to promote the establishment of native tree seedlings.

A number of physical and biological parameters have been monitored throughout the project. Shallow groundwater wells (piezometers) were set up at various distances from the bank to see how groundwater is affected by river flow, distance to the riverbank and distance to the old, established bosque. Vegetation was sampled throughout the lowered bar area to monitor which herbaceous and woody species came onto the cleared site. Soil salinity was measured and soil textural types identified. A fenced weather station was erected at the site's north end. Surface-active arthropods, bird populations and beaver activity were monitored on the new bar as well as in the adjacent cottonwood bosque and in an uncleared Russian olive thicket north of the site.

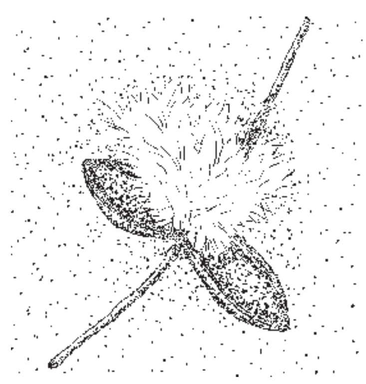
The site flooded in May and June of 1998. Flooding occurred at flows over approximately 2,500 cubic feet per second (cfs). In 1999, there were three overbank inundations: in late May–early June, late June and early August. Relatively elevated parts of the site did not flood, even at flows approaching 5,000 cfs. Groundwater levels correlated well with Rio Grande stage heights and discharge rates measured at the Albuquerque Central Avenue Bridge USGS gages. Groundwater response was most rapid and had the greatest amplitude in wells nearest the bank.

Changes in river channel morphology (shape) were quite notable. Prior to restoration activities, the river channel adjacent to the site maintained uniform depth, velocity and width for variable river discharges. However, because of the extensive erosion changes in the bank profile and in site topography, the river channel is now much more variable in depth, width and velocity for variable discharges. Since bank-stabilizing Russian olives are now absent, the river has eroded 125 to 150 feet (37.5–45 m) of bank line, with river width increased by 15 percent. New bar formation has occurred downstream as the eroded bank material has been relocated.

Over 8,000 cottonwood seedlings and a smaller number of coyote willow, saltcedar and Russian olive were established during the first flood season. Most of the cottonwoods died before the second season, but the remaining patches are conspicuous in places (some were six to seven feet (1.8–2.1 m) tall in 2001) and account for more cover than do survivors of other woody species. They occur in sandy-loamy soils that characterize much of the site. Relative saline soils at the northern end of the experimental area supported large sunflower stands the first summer. These were largely replaced by sweet clover the second summer. Cockleburs and horseweed are common toward the site's southern end.

The new bar habitat greatly increased the number and diversity of animals using the site. A number of bird and arthropod species were detected on the new bar that were not present in the adjacent mature bosque. Beavers were active cutting young cottonwoods and willows, but as of the summer of 2001 had not had a large impact on the new vegetation overall. Animal use of the bar will likely change as the vegetation changes over the years, but overall the project was beneficial to animal populations.

The AOP provides a good demonstration of the type of new restoration projects currently being done along the Middle Rio Grande Valley. It also shows the effectiveness of bulldozer ecology.



A tetone shedding "cotton"

13. Changing River

The Base Activity for the Middle Rio Grande Model

Description: In a directed class activity, students construct a paper and cloth model of a section of the Rio Grande Valley as it was before major human intervention, and then manipulate it to demonstrate the human-caused changes over the last century. In the context of today's river, the students contrast the differences between managing the river for only human benefits and managing the river with broader objectives of both ecosystem health and human needs. They then construct a model of the river of the future using those broader objectives.

Objectives: Students will:

- model the conditions of the old river (Rio Bravo);
- describe the way the river has been significantly altered by humans in the last century (Rio Manso); and
- predict the way the river can be managed to support a healthy ecosystem (Rio Nuevo).

13. Changing River

Grades: This model can be used with all ages, from kindergarten through adult, with discussion geared to the appropriate level. The discussion in this write-up is geared for Grades 3–8.

Time: Initial material preparation: about 30 minutes. Activity: a minimum of one hour to assemble the river, learn where the components are placed, and summarize how the river changes. This activity can be paired with others ("Who Lives Where," "Who Grows Where," "Cottonwood Creation," etc.) and can take many class periods.

Subjects: science, social studies, language arts

Terms: *acequia, biodiversity, bosque, decomposers, flood pulse, jetty jack, levee, meander, mosaic, nutrient cycling, oxbow, riparian, riverine, sandbar, sapling, seedling, snag*

New Mexico STEM Ready! / Next Generation Science Standards

NGSS DCIs and New Mexico State Performance Expectations

3.LS1.B Growth & Development of Organisms
3.LS2.C Ecosystem Dynamics, Functioning & Resilience
3.LS4.C Adaptation
3.LS4.D Biodiversity & Humans
3.ESS3.B Natural Hazards
4.ESS2.A Earth Materials & Systems
4.ESS3.B Natural Hazards
5.ESS3.C Human Impacts on Earth Systems
5.ETS2.A (5-SS-1 NM) Interdependence of Science, Engineering & Technology
MS.LS2.A Interdependent Relationships in Ecosystems
MS.LS2.C Ecosystem Dynamics, Functioning & Resilience
MS.LS4.D Biodiversity & Humans
MS.ESS2.C The Roles of Water in Earth's Surface Processes
MS.ESS3.A (MS-ESS3-3 NM) Natural Resources
MS.ESS3.C (MS-ESS3-3 NM) Human Impacts on Earth Systems
MS.ETS2.B (MS-ESS3-3 NM) Influence of Engineering, Technology & Science on Society & the Natural World

NGSS CCCs

Patterns; Cause & Effect: Mechanism & Explanation; Scale, Proportion & Quantity; Systems & System Models; Energy & Matter: Flows, Cycles & Conservation; Stability & Change

NGSS SEPs

Asking Questions & Defining Problems; Developing & Using Models; Constructing Explanations & Designing Solutions; Engaging in Argument from Evidence; Obtaining, Evaluating & Communicating Information

Materials:

For assembly:

- Scissors to cut the pieces
- Envelopes or plastic sandwich bags to hold the pieces and information cards
- Copy of information cards on pages 184-193 or kit materials from workshop
- Five copies of model components (pages 302–303) or kit materials

Your class can then make the following sets:

Before alteration pieces (Rio Bravo):

100	Cottonwood Seedlings
20	Cottonwood Saplings
10	Big Cottonwood Trees
100	Cattails
5	Sandbars
5	Grassy Meadows
15	Native Riparian Shrubs
15	Upland Shrubs

After alteration (Rio Manso):

20	Houses
20	Jetty Jacks
30	Exotic Riparian Trees
10	Snags / Downed Wood
2	(or more) Irrigation Ditches and Drains (see below)
2	Levees
10	Agricultural Fields
1	Dam
10	Additional Big Cottonwood Trees
5	Additional Upland Shrubs

Restoration pieces (Rio Nuevo):

6	Monitoring Plots

Have students cut out the pieces. Place all of one kind into an envelope or sandwich bag and include the information card for that feature. Keep the *Rio Bravo*, *Rio Manso,* and *Rio Nuevo* pieces separate.

Additional model components (by color and/or instruction):

- One tan, white, or brown blanket, sheet, or large cloth at least 6 to 8 feet (2 to 2.4 meters) long for the Rio Grande Valley
- Strips of blue fabric about 6 to 12 inches (15 to 30 cm) wide for the river. Length should be about three times the length of the valley (blanket, etc., above). You can make long cuts lengthwise in the fabric for braids and meanders. Small separate pieces can be used to construct oxbows or ponds.
- Two brown ribbons or thin fabric strips for levees, 8 feet (2.4 meters) long each
- Blue ribbons for ditches or drains, two 8-foot (2.4-meter) ones and other shorter lengths to reach to fields from the river (The activity "Working Water" requires additional sizes and colors of ribbons for ditches, drains, etc.)
- Green and brown construction paper or felt for agricultural fields, various sizes (long, narrow for ditch-served fields, rectangular or square in some areas), varying from 2 to 5 inches (5 to 12.5 cm)

Note: A chart showing the number of model pieces needed for each river scenario follows below.

Note: Participants attending a *Bosque Education Guide* workshop receive color-coded, laminated model components. Kits can also be created using the model component pages in this activity.

Background:

In this activity students construct a model of a section of the Middle Rio Grande Valley. Models are tools that help us understand complex systems by simplifying their components. We use models to help demonstrate ideas that are not as easy to grasp when working with a real ecosystem.

One way to understand the relationship of the bosque to the Rio Grande is to think about the Rio Grande as “different rivers” depending on time. Long ago, the Rio Grande functioned much differently than it does today. Although people have used the river’s water for irrigation for probably thousands of years, they did not start capturing the river water behind large dams or changing the river’s natural hydrological functions until this past century. In the model we call this old river ***Rio Bravo***, which is the historic name for the Rio Grande meaning wild or brave—an untamed river.

In contrast, we call the river that has been highly altered by humans ***Rio Manso***. Manso is a Spanish word that means tamed, such as a horse that has been broken to riding. For many years, changes were made to the river system with the top priority being how the river was serving human society. Little attention was given to the ecosystem and the other animals and plants that depended on this important riparian corridor. In 1993, an important document, the *Middle Rio Grande Ecosystem: Bosque Biological Management Plan*, brought a focus on the problems of prioritizing river management for human needs only.

Many projects before the *Plan* attempted to address biological issues on a small scale, and since its publication river managers have been more active in managing the river for both human needs and ecosystem health. In our model exercises, we call this third river ***Rio Nuevo***—a new river that meets human constraints but provides a healthy ecosystem with as many of the Rio Bravo features as can be allowed. This river will always be evolving. In actuality, there will always be places along the river that are more like Rio Manso and other places that are more like Rio Nuevo. When students ask what river we have today, we can tell them we have both, depending on the location.

Photograph courtesy of the Friends of the Rio Grande Nature Center.

"Changing River" Model Pieces

What to Have on the Model When

	Rio Bravo	Rio Manso	Rio Nuevo Summary	Habitat Restoration Projects (Rio Nuevo)								
				Overbank Flooding	Pole Planting	Wetland construction	Fuel-wood reduction	Secondary channels	Exotic species removal	Water conservation	Jetty jack removal	Monitoring along river
Cottonwood Seedlings	**100**	**10**	**75**	**10**		**5**		**40**		**5**	**5**	
Cottonwood Saplings	**20**	**1**	**11**		**10**							
Big Cottonwood Trees	**10**	**20**	**20**	**1**	**1**		**-1**	**1**	**1**		**-3**	
Cattails	**100**	**5**	**73**			**50**		**10**		**5**	**3**	
Sandbars	**5**	**2**	**5**					**2**			**1**	
Grassy Meadows	**5**	**1**	**4**				**1**		**2**			
Native Riparian Shrubs	**15**	**7**	**13**	**2**		**1**	**1**	**2**				
Upland Shrubs	**15**	**20**	**17**	**-1**		**-1**		**-1**				
Houses	**–**	**20**	**19**	**-1**								
Jetty Jacks	**–**	**20**	**12**					**-3**			**-5**	
Exotic Riparian Trees	**–**	**30**	**11**	**-1**		**-1**	**-5**	**-1**	**-10**		**-1**	
Snags/Downed Wood	**–**	**10**	**5**	**-1**			**-4**					
Irrigation Ditches/Drains	**–**	**2**	**2**									
Levees	**–**	**2**	**2**									
Agricultural Fields	**–**	**10**	**10**									
Dam	**–**	**1**	**1**									
Monitoring Plots	**–**	**–**	**6**									**6**

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Procedure:

Introduction to "Changing River" Model

- Have students make a KWL chart (see Appendix K**)**. Ask the question:

  *What do we **Know** about the bosque—the area near the river?*
  *What do we **Want** to know about the bosque?*

  After the lesson, revisit the chart and ask, *What have we **Learned** about the bosque?* Remember to come back to the KWL chart frequently to show what students have learned and to encourage new questions! **(Asking Questions & Defining Problems)**

- You can also use the lens of **Systems** to learn about the bosque ecosystem. For example, you can look at a cottonwood tree as a system itself, or as part of a larger bosque ecosystem. Brainstorm with students: Boundaries, components, interactions, inputs and outputs, properties.

  Here are more tips for using a Systems lens:

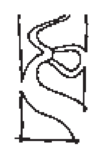
  1. Look for the bigger picture.
  2. Study systems from multiple perspectives.
  3. Consider the role of short and long time frames.
  4. Search for complex cause and effect relationships.
  5. Explore places where systems connect with other systems.

  --*WestEd/Making Sense of Science* **(Systems & System Models)**

Vocabulary for Introducing Rio Bravo

bosque: (BOH-skay) Spanish word for "woods"; in the Southwest it is used to describe the forest of trees along a river

riparian: (Latin root means "at a river") relating to or living or located on the bank of a natural fresh watercourse such as a river, stream or pond



oxbow

oxbow: U-shaped river channel that has been cut off from the main flow of a river causing a pond or lake to form

meander or bend in the river: the manner in which a river bends or curves

meander

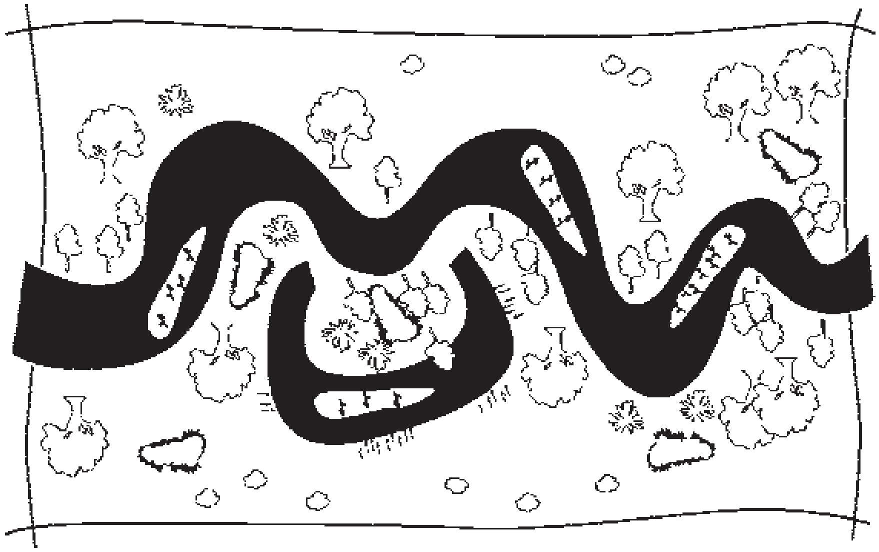
braid in the river: the manner in which a river splits into several channels forming islands between the waterways

seedling: a young plant grown from a seed. Often refers to a tree that has germinated or sprouted, but has not reached sapling size; ("baby trees")

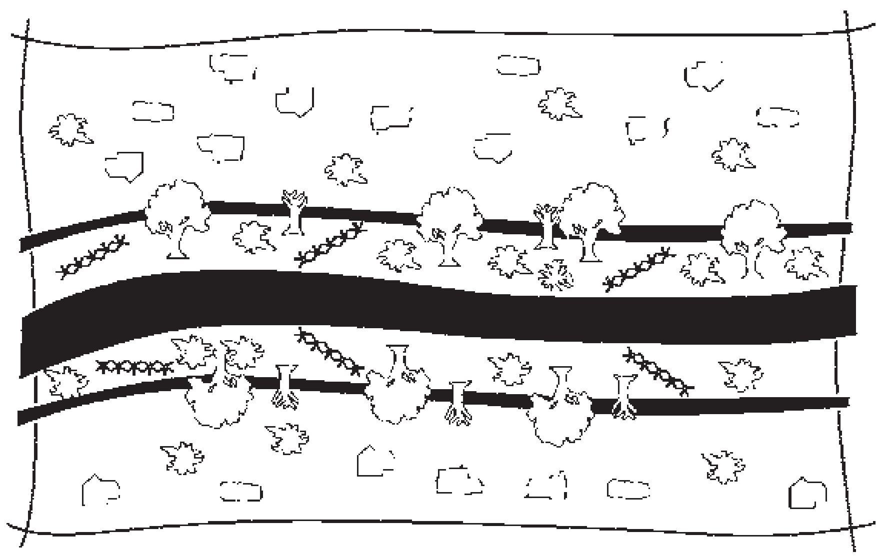
braid

sapling: a young tree, generally taller than 4.5 feet (1.5 meters) and less than 4 inches (10 centimeters) in diameter at breast height (dbh; "teenage trees")

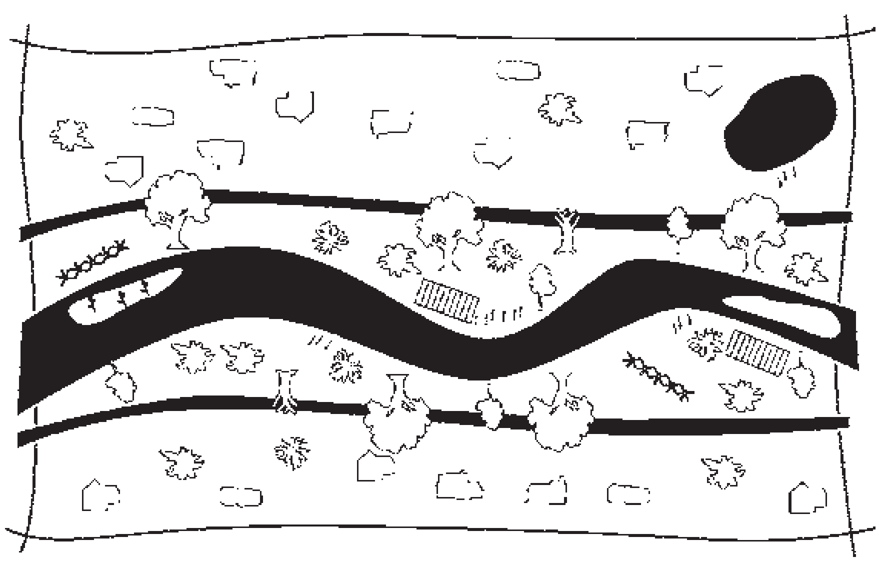
(See ***Terms*** for other words to introduce to your students.)



Rio Bravo



Rio Manso



Rio Nuevo

Pre-model Discussion Questions

*What is in a bosque? (*Water, trees, animals, bugs, soil . . .)

What animals have you seen in the bosque?

What is the main native tree in the Rio Grande bosque? (Cottonwood)

How does the bosque differ from the higher area surrounding the bosque? Are the same plants in the bosque and in the higher areas surrounding the bosque? (Keep in mind that cities will water yards and parks in the upland areas, but in natural areas there are very different plants and animals.)

What makes the bosque different? (The water! Get your students to think through this, it is a very important concept.) In addition to the river itself, the water table is near the surface and many riparian plants can reach down to get water. **(3.LS4.C)**

Cottonwood trees are very important to the bosque. *Can anyone tell me how they reproduce? What type of seeds do they have?* (The seeds are attached to fluffy cotton and they are carried by the wind up and down the river. They need special conditions in order to sprout: wet soil, an open area with lots of sunlight, and the roots must be wet as they grow—during the summer the groundwater drops, and if the roots of the sprouted seeds don't stay wet the seedlings will die). **(3.LS1.B)**

Floodplain showing different levels of sandbars along the Rio Grande
Photograph by Letitia Morris

Section A: Rio Bravo

Setting Up the Rio Bravo Model

- Initiate the activity by explaining to students that they will be building a model of the river and the bosque.
- Lay out the basin (blanket, sheet or other material) with raised edges along the two longest (opposite) sides. Since you may want the students walking on the model without shoes, suggest they place their shoes under the material to create the raised edges (valley); lunch boxes or books work, too. Students may raise all four sides of the basin at first. This is an excellent opportunity to discuss closed basins and explain that long ago, before the Rio Grande was a river, it was a series of lakes in closed basins. Then adjust the model so the two shortest sides are not upraised to emphasize that it is now a valley, with the river coming in one end and out the other end.
- Place the river down the center of the basin. Explain that since they are laying out Rio Bravo, the river should have:
  - large meanders or turns
  - oxbows—old abandoned channels separate from the river that are marsh areas (use small pieces of cloth)
  - braids—loop the fabric or make slits in the river material to represented the braided river
- Hand out only the Rio Bravo (pre-alteration) envelopes or baggies to the students. Teams can be given the larger number of items.
- Ask students to read the card and figure out where in the basin their pieces should be placed, and then place them. Pay close attention to the directions for each of the items in the bags.
- Go around the class with each student/group discussing why their item was placed where it was. Have students use their own words to explain their choices.
- Explain that this is what the river was like before humans made changes to the river.

Essential Rio Bravo Observations

Have the students describe the landscape they have created.

(The end result is a **mosaic** of mini habitats. A grove of old cottonwood trees here, a group of teenage trees (saplings) there, and baby trees (seedlings) in another spot. There was not a continuous forest of large cottonwoods along the river, but a patchwork of different-aged stands of trees. Each year the river might change course, taking out plants that had been there, but providing new open areas for seeds to get established. This mosaic created stability in habitats across the floodplain, and this spatial pattern was stable when considered over time.)

What role does spring runoff play in the ecosystem?

(Every three to five years the river would flood over its banks due to high runoff from snow in the mountains. This is called the **flood pulse**. During overbank flooding in spring, river water saturates the branches and leaves that have fallen on the ground in the bosque. This wet debris decomposes more quickly than dry leaves and sticks. Microscopic organisms such as bacteria and fungi feed on the downed material. The dead material is broken down into nutrients used by other plants. This is called **nutrient cycling**. Flooding promotes nutrient cycling. Flooding also structures floodplain habitats. For example, it creates wet areas for cottonwood seedlings, deposits nutrient-laden sediment into the forest, and may alter the channel of the river.) **(3.LS2.C; MS.LS2.C)**

Rio Bravo Discussion Questions *(after model has been laid out by students).*

Look for patterns. The Rio Grande once experienced temporal patterns in flooding that structured floodplain ecosystems and determined the species that survived there. Flooding also created spatial patterns in habitats.

What patterns can you see for Rio Bravo over time (what natural cycles were present temporally?)

Look for different plants living in different levels along the river, e.g., upland shrubs, wetlands, etc.

Are there patterns of where species can find the right conditions to survive?

(Patterns)

Consider specific plants and where they occur, such as cattails.

Where do cattails survive well? Where do they not survive?

Consider this for other plant species that have been placed on the model.

(3.LS4.C; MS.LS2.A)

The Rio Grande was once a dynamic system that changed greatly over time and space within the floodplain. Changes were much less predictable at a small spatial or temporal scale, but habitats were predictable when considered over a longer time or larger area. Look at the changes in habitats due to flooding and erosion, and consider how these affect organisms living in a given location.

What is the natural cycle of the river through time (within a year and across years)?

Did habitats change naturally? If so how? What caused these changes?
How is snowfall in the mountains related to flooding in the bosque?
How does the amount of mountain snow affect plants and animals living in the floodplain?
In what ways does flooding shape habitats in the floodplain along Rio Bravo?
How might flooding create stability over time and across space?
How does water restructure sediment within the floodplain, such as the distribution of sandbars?
How do the changes in the habitats affect the organisms living there?
(4.ESS2.A; MS.ESS2.C; Cause & Effect; Scale, Proportion & Quantity; Stability & Change)

The amount of water flowing in the river reflects the energy in the system; energy is the ability to bring about change. More water in the river means more potential to make changes to the system, such as moving sediment, rocks or logs.
Does the high volume of flow cause changes in the bosque ecosystem? If so, in what ways? Consider both physical changes and changes in the composition of species that are present.
How did the floodplain change over time, particularly as relates to energy input?
(3.LS2.C; Scale, Proportion & Quantity; Energy & Matter)

At this point, you may want to proceed on to Section B, *Transitioning to Rio Manso*, or you may want to do the first parts of "Cottonwood Creation," "Who Lives Where?," "Who Grows Where?," "Bosque Chaos," and/or "Changing Fire".

Section B: Transitioning to Rio Manso

- Pass out the components for Rio Manso (the changed, tamed or altered river). Following the timeline below, have students restructure the river adding the new components and taking away older components as indicated by the timeline events. (See Appendix D: Human Chronology). Items with a ✓ give instructions for making changes to the model. This timeline addresses the valley between Cochiti Dam and Elephant Butte, so it may need to be adapted for other locations.

cottonwood catkins
(male, left, and female)
Photographs by Nolan Hester

Going from Rio Bravo to Rio Manso: Timeline for the Historical Rio Grande

Let us take a moment to recognize that we are on the land of the Indigenous People of the Tiwan Province—the Tiwa-speaking (TEE-wan/TEE-wa) people who live here today and who have lived here for many centuries.

2,000 years before present: The earliest horticulture was practiced here in the Rio Grande Valley. People mainly planted seeds along upper canyons and washes and relied on rain to provide moisture for plant growth.

✓ add one small agricultural field

AD 500-900: Semi-permanent small villages of pithouses were settled along the Rio Grande; the main agricultural crop was corn.

✓ add one pueblo-style house

AD 1275–1300: A major drought struck across the Southwest and many areas without permanent water were abandoned. Because of its reliable water, the Rio Grande became a focus for settlement. The population of the valley increased and pueblos made of adobe were built on both sides of the river. The people grew corn, beans, squash and cotton.

✓ add another pueblo-type house

✓ place a few agricultural fields

AD 1540-1598: First European explorers reached central New Mexico; Pueblo cultures were greatly impacted and had to change to meet these new cultural challenges.

1600s: The Pueblo people were consolidated into a few villages; the abandoned areas were readily colonized as ranchos by Spanish settlers.

✓ add four more houses along the river

1706: Albuquerque was founded as a villa real, or royally recognized town.

1874-1941: Large floods occurred in 1874, 1884, 1891, 1903, 1909, 1912, 1920, 1937 and 1941. There had been overgrazing in the hills; water sped off the land to the valley. There were few plants to hold the soil and slow the flow of water. Sediments filled the river channel. The water table of the valley was very high with standing water—fields were flooded and did not drain.

1885: A dike was built to protect "New Town," Albuquerque's downtown area where the new railroad had just been built. There was a lake in Los Ranchos for a month, but the soil was left enriched.

✓ add five more houses

✓ (option) use levee material doubled up to build "small dike"

1925: The Middle Rio Grande Conservancy District was formed to provide irrigation, drainage and flood control for the valley. Deep ditches called drains or clear ditches were built to remove standing water from farm fields. Levees were built for flood control and ditches to deliver water, called acequias (a-SAY-kee-uz), were improved.

✓ place levees along each side of the river on the model.

What happens to the river channel when levees are added? (The river was straightened and narrowed; see diagram earlier in activity.)

What happens to the marshes when the drains are installed? (Drains are used to lower the water table to decrease waterlogging of farm fields.)

✓ add the longest “drains” just outside of the levees

✓ remove about 95 cattails (leave 5) showing a decrease in marsh areas

✓ add more agricultural fields

1930s to 1990s: exotic saltcedar/tamarisk spreads through the valley. Saltcedar and Russian olive were introduced in the late 1800s as ornamental plants and to help drain water from marshy areas.

✓ add exotic riparian trees

1941: The levee was breached for the last time that century, and there were two months of standing water in town. If you walk between the levee and the river at the Rio Grande Nature Center State Park, many of the cottonwood trees you see sprouted during that 1941 flood year.

1957: There were major efforts to control the river after World War II. The levees were improved and many “Kellner” jetty jacks were installed to protect the levees.

✓ add jetty jacks to protect the levees and keep the river in its channel

✓ add the rest of the houses

✓ remove about 90 seedlings (leave 10), since lack of flooding means reduced natural regeneration; leave remaining seedlings on sandbars and immediately adjacent to river

1975: Cochiti Dam was completed and began filling. *What effect does a dam have on a river?* (This eliminated flooding, reduced sediment/sand and straightened the river channel.)

✓ add a dam at the up-river end of the model

✓ replace 19 cottonwood saplings with 10 additional mature cottonwood trees to show that no new tree recruitment is going on, but the trees in place are getting older

✓ remove three sandbars to show that Cochiti Dam traps sediment. The water flowing through is clear until it picks up sediment from the channel downstream. This sediment scours the channel and decreases sandbar formation.

Some of the gradual changes since 1975:

✓ add the burned snags: there are more fires with more people living in the valley

✓ add five more upland shrubs into the riparian area, because the water table is dropping and the bosque is losing its hydrological connection with the river allowing plants tolerant to drier conditions to become established.

Students should have made the following changes to the model:

- The number of cattails has decreased, since slow or standing water is harder to find (occasionally found near the sides of sandbars).
- The river is relatively straight. Curves are there, but no large meanders, oxbows, etc. Sandbars are still present, but braiding is greatly reduced.
- The river channel is narrower.
- There are levees on each side of the river channel. (There should be only a few inches between each levee and the riverbank.)
- There are jetty jacks between the river and levees.
- Irrigation ditches provide water to the valley.
- The majority of the mature cottonwood trees are between the riverbank and the levees. Some large trees can still be found elsewhere in the valley.
- The number of cottonwood seedlings and saplings has decreased. Seedlings can be on sandbars, but are frequently washed out, so rarely reach sapling size.
- There is a reduction in native shrubs and an increase in exotic shrubs; these are found primarily in the strip of land between the river and the levees.
- There are clumps of snags or burned trees within the bosque from human-caused wildfires (exotic shrubs are often underneath these snags).
- There should be a dam across the upper edge of the valley from upland to upland.

Rio Manso Discussion Questions

Consider how the floodplain environment/habitats change between Rio Bravo and Rio Manso (and Rio Nuevo after the next section). Humans have caused these changes by interrupting the annual flood cycle, installing drains, etc.

What has changed about each habitat, and how do those changes affect the species that survive there?

What kinds of habitats were available in Rio Bravo that are less available in Rio Manso?

Which plant species are able to survive well, less well, or not at all?

What will eventually happen to the cottonwood trees if there are not enough new seedlings to take their place?

How do changes favor saltcedar over cottonwoods?

Look for upland shrubs moving into the floodplain; why are they there?

Do you think the same animal species can live along both river systems? Which species might or might not survive?
(3.LS2.C; 3.LS4.C; 3.LS4.D; MS.LS2.A; MS.LS2.C)

Human settlement within the floodplain meant that the natural process of flooding became a natural hazard that affected human communities.

How were humans affected by natural hydrological processes along the Rio Grande?

How did humans reduce the impact of flooding? What have humans done to protect their towns and cities from floods? **(3.ESS3.B; 4.ESS3.B)**

What are the effects of these human activities on native plants and animals? **(5.ESS3.C; MS.LS4.D; MS.ESS3.C)**

Consider again the natural, dynamic nature of the river and floodplain, changing in time and space, and the impact of human alterations on this ever-changing system. Humans have not only reduced the peak spring flows but have increased the summer flows as water is apportioned throughout the irrigation season.

How have humans changed the dynamic cycle of the river?

Do these changes promote stability in the system overall?
(Patterns; Stability & Change)

Many of the changes that have occurred along the river are irreversible. For example, it will be impossible to eradicate all of the introduced plants, and some species are now extinct and can never come back, such as the Shovelnose sturgeon. We can't let the river run wild as it did before, because it would flood people in places such as Alameda, Corrales, Old Town and downtown Albuquerque.

Do you think anything can be done to make Rio Manso more like Rio Bravo?

Let students brainstorm. This is a lead into the next step: transforming the river to **Rio Nuevo**.

Consider the system from an engineering point of view:

How have we kept the river from destroying our communities in high water?

What aspects of the engineering solutions to flooding and to agricultural needs have had negative effects on the species in the ecosystem that were not known at the time of construction? **(Asking Questions & Defining Problems)**

At this point, you may want to proceed on to Section C, *Transitioning to Rio Nuevo*, or you may want to continue Rio Manso-related activities: "Cottonwood Creation," "Who Lives Where?," "Who Grows Where?," "Working Water," "Bosque Chaos," and/or "Changing Fire."

Section C: Transitioning to Rio Nuevo

Today's land managers know more about the potentially negative effects of the major projects installed along the Rio Grande in the 20th century than did earlier managers. They are now taking measures to ensure the maintenance of a variety of habitats that will provide appropriate places for the natural biodiversity of the valley and improve the situation for some endangered and threatened species.

- Let's think about ways to make Rio Manso more like Rio Bravo. Encourage students to come up with original ideas and make changes to the model. This is a good opportunity to focus on defining engineering problems related to restoration. For example, *Can we think of projects that will help to restore the river and bosque to the way it was in Rio Bravo?*

  How can we create more wetland habitat for bosque species?

  How might we help establish new cottonwood trees and other native plants?

  How might we decrease the risk of fire?

  Encourage students to come up with original ideas and make a list. They

may make those changes to the model or find similar projects on the cards to help them make changes.
(5.ESS3.C; MS.ESS3.C; Asking Questions & Defining Problems)

- Next, divide students into nine teams based on the Rio Nuevo Habitat Restoration Project cards (one per team). Look at the cards for ideas of additional projects they might implement and make those changes on the model. (Another option is to have the class work as a group on each project. This works particularly well with small class sizes.)
- Have each team tell the class what their project was and what changes they made on the model. Explain that we call this new river, in which humans are trying to restore characteristics of Rio Bravo within existing constraints, **Rio Nuevo**.
- You might share the story of an actual restoration project, "Bulldozers in the Bosque" (page 160), to discuss a real-world project, the Albuquerque Overbank Project, and its effects.

Rio Nuevo Discussion Questions

Ask the students to explain the differences between Rio Nuevo and Rio Manso. For example, Rio Nuevo has

- more natural river features, such as meanders, oxbows and braids
- more opportunity for the next generation of cottonwood trees to germinate
- fewer exotic species

Today's river has elements of both Rio Bravo and Rio Manso.

Ask students to give examples of aspects of each river that can be found in Rio Nuevo:

Rio Bravo: pole plantings (saplings), fewer exotics, constructed wetlands, etc.

Rio Manso: levees, jetty jacks, Russian olive trees, saltcedar stands, etc.

Look at the Changing River model to consider changes to the physical valley including sandbars and the river channel.

How has the physical landscape changed across Rio Bravo, Rio Manso and Rio Nuevo, and how do those physical changes affect the species living there? Compare the shape of the river channel in Rio Bravo, Rio Manso and Rio Nuevo. **(4.ESS2.A; Patterns)**

Drought is now more frequent in the Southwest due to climate change. Note that cottonwoods are susceptible to drought and the resulting lower water table. Mature cottonwoods will die if the water table drops below 3 meters/10 feet. Trees combat climate change by taking in carbon dioxide (CO2), a powerful greenhouse gas, during photosynthesis. So, human activity that affects cottonwoods in the bosque affects climate change.

How does drought affect cottonwoods?

What do cottonwoods need to survive?

What role do cottonwoods and other trees play in protecting us against climate change?

(3.LS2.C; 3.LS4.C; 5.ESS3.C; MS.LS2.C; MS.ESS3.A)

At this point you may want to continue with model activities "Cottonwood Creation," "Who Lives Where?," "Who Grows Where?," "Bosque Chaos," and/or "Changing Fire" that have Rio Nuevo sections.

Assessments:

- Revisit the KWL charts, focusing on what students have learned. *What have we **Learned** about the bosque?*
- Write a Claim, Evidence, Reasoning statement about:
  - The effect of flooding on the bosque.
  - The effect that human alterations have on natural flooding, and how this has affected the distribution of floodplain habitats along Rio Manso.
  - The effect of dams/levees/jettyjacks on the river, bosque or floodplain.
  - The role that land managers can play in restoring the health of floodplain ecosystems along Rio Nuevo.
  - How to improve conditions for endangered species.
  - The effect of climate change on drought and extreme precipitation events in the region and how those affect the bosque.
  - Changes in the habitats along the river affect the system's ability to withstand flooding. With current changes to the floodplain, could the system withstand flooding after an extreme rainfall event? **(MS.ETS2.B; Cause and Effect; Stability & Change; Constructing Explanations & Designing Solutions; Engaging in Argument from Evidence)**
- Devise a design solution about how to improve habitat in the bosque, the river or the floodplain. **(Constructing Explanations & Designing Solutions)**

Unit-Level Assessments

- **Build Models:** After building the class model of the bosque ecosystem, students can make their own model illustrating the three rivers over time, or some particular aspect of the river. This could be done at the end of each section (Rio Bravo, etc.) or after all three rivers have been completed. They can draw on paper or white board, make a 3-D model, video or photos, etc. **(Developing & Using Models)**
- To celebrate finishing the River of Change unit have students decorate three cakes for the three different river models they studied. Materials: three sheet cakes with plain icing; squeeze icing in different colors. Divide class into three teams, assign each team either Rio Bravo, Rio Manso, or Rio Nuevo. Have them decorate their cake appropriately. A spokesperson for each team then tells the rest of the class what they put on their river model. Then have a party and eat the cakes! **(Developing & Using Models)**
- **Writing:** Have students write about the differences between the rivers, what changes have occurred and what is being done to protect and restore the ecosystem today. Write letters, flyers, posters or books to show learning about human impact design problems, i.e., reducing the number of jetty jacks; cleaning water from/in the river. **(Obtaining, Evaluating & Communicating Information; ELA/Common Core standards)**

***Book Writing* (ELA Standards)**
After students have participated in the Changing River model, they have the experience and information to write a book. There are many Common Core English Language Arts Standards that will be addressed in this activity. Use a children's book to follow as a template. A wonderful example is *A River Ran Wild* by Lynne Cherry. This beautifully illustrated book describes the changes over centuries that occurred to the Nashua River in New Hampshire and Massachusetts. After reading the book several times, use the format to write a new book about the Rio Grande, incorporating the information from the Changing River activities. Write and rewrite the new book as a group, then print the text on multiple pages with room for the students to illustrate. The format used by Cherry includes very detailed illustrations and this could inspire all students to draw and label plants and animals of the Rio Grande.

Suggested adaptations

- Do a felt-board example of the basic items that are part of the bosque—a river, cottonwood trees, sandbar, etc. before working with the model of the river. Place a Velcro dot on some River Model pieces for use on the felt board.
- What animals live in the valley? Think of the needs of ducks and cranes they might see along the river—what do they find in the valley that they need?
- Discuss what trees need in order to live: sunlight, carbon dioxide, soil nutrients and **water**. We provide water for the trees at school and home. In the bosque tree roots must reach the water in the ground.
- Research: Have the students research the animals that live in the bosque. Put together a book or poster about the animals. Use these projects to teach younger students.

North American Porcupine
Illustration by Reese Bice

- Have older students learn the "Changing River" activity and then teach younger students using the model.
- Reduce the number of plant pieces by half to reduce visible clutter.
- 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 plants on a field trip activity
- Introduce the model cards before activity (what do students know before?) Review before resuming activity (what do students remember?) Review after activity (what did students learn?)
- Use repetition and repetitive patterns to support reading in this 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).
- Place a frame to isolate parts of the activity while in process. Ask groups to describe what is happening in that section.
- 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.
- Conduct 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?

Extensions:

- Until relatively recently, flooding in the Rio Grande Valley was a common and often devastating occurrence for human settlements. The math worksheet "How Long Ago?" (page 187) will help students realize that floods occurred in the Albuquerque region in the not too distant past. Make a copy of the worksheet for each student. Have students subtract the year for each event listed from the current year to determine how long ago these floods occurred.
- Have students pay attention to the news for items related to the bosque and the river. There are many issues that regularly appear in the news: endangered species, water planning/water sources, fires, clean-up activities, etc. Post newspaper items in the classroom; have students report on the news they have heard to the rest of the class.

- Look at different time windows on the river—Rio Bravo, Rio Manso and Rio Nuevo. *How has the volume and energy of the water in the river changed over these times? Where has the water gone? How has its flow changed? What effect does that have on the structure and functioning of the floodplain ecosystems?* **(Scale, Proportion & Quantity; Stability & Change)**
- There are numerous topics available for students to research further. For example, students can investigate how changes to the natural river system, such as the installation of dams and levees and the lowering of the water table, affect the distribution of habitats across the floodplain. Evaluate the importance of flooding in maintaining the diversity of habitats, and the impact of human changes on the system. Share these ideas orally, or by writing letters, flyers, posters or books. **(Obtaining, Evaluating & Communicating Information)**
- Student research: Consider conservation and restoration. *How can humans ensure the energy and matter needs of native species into the future? What is needed to understand the requirements of native species?* **(Energy & Matter)**

NGSS Connections to Changing River - Disciplinary Core Ideas
[Middle School details in Appendix K]

3.LS1.B Growth and Development of Organisms *Reproduction is essential to the continued existence of every kind of organism. Plants and animals have unique and diverse life cycles.*

Cottonwood trees are very important to the bosque. In this activity we focus on three life stages of cottonwoods and the conditions they need in each.See also "Cottonwood Creation".
How do cottonwoods reproduce? What type of seeds do they have?
What conditions do cottonwoods need to get started growing (germinate)?
How do they manage to survive to old age?

3.LS2.C Ecosystem Dynamics, Functioning and Resilience *When the environment changes in ways that affect a place's physical characteristics, temperature, or availability of resources, some organisms survive and reproduce, others move to new locations, yet others move into the transformed environment, and some die.*

Rio Bravo: In the prehistoric era, noticeable changes occur across the seasons. One example is the impact of high water on the ecosystem. Cottonwoods germinate on wet soil exposed as the floodwaters recede.
What is the role of the annual spring runoff/flood pulse in this ecosystem?
Does the high water cause changes in the bosque ecosystem? If so, in what ways? Consider both physical changes and changes in the composition of species that are present.

Think about what changes are tolerated and what are not.
An example is plants that tolerate flooding. Willows bend in high river flow and straighten/bounce back once the water recedes. Cottonwood bark can withstand logs running into it in high water.

Rio Manso and current conditions: Over the last century humans have made many changes to the river, such as building levees, dams and agricultural diversions, that have interrupted the annual flood cycle and resulted in changes to the bosque ecosystem.

Compare Rio Bravo to Rio Manso.
Look at introduced species such as saltcedar and the effect on native cottonwoods.
Look for upland shrubs moving into the floodplain—why are they there?

Rio Nuevo: Land managers today have the results of scientific research to help them refocus their work to keep as many aspects of Rio Bravo as possible in future river management projects.
Compare Rio Nuevo to Rio Manso and Rio Bravo, what aspects of each do you see?

There are future concerns such as more frequent drought in the Southwest due to climate change. Land managers and engineers have to be creative in providing conditions for long-term survival of cottonwoods. Cottonwoods are susceptible to drought and resulting lower water table (Mature cottonwoods will die if water table drops below 3 meters/10 feet.)
What do cottonwoods need to survive?

3.LS4.C Adaptation *For any particular environment, some kinds of organisms survive well, some survive less well, and some cannot survive at all.*

Compare species in different environments/habitats during each time period: Rio Bravo to Rio Manso to Rio Nuevo. Illustrate the conditions that are changing between environments—species may survive well, less well or not survive.

What species are in each category? Examples—cattails survive well in wetlands, not in the river itself—they are adapted to shallow water, and places that are wet most of the year. Saltcedar survives well under Rio Manso conditions.

Look at other categories of plant species on the model—native riparian shrubs, cottonwoods, upland shrubs, exotic riparian trees and what conditions they are adapted to do well in.

How does changing the habitat affect the species that live there?

What kinds of habitats were available in Rio Bravo that are less available in Rio Manso?

Which species are able to survive well, less well, or not at all as the habitat changes?

What do cottonwoods need to survive? Are these conditions available in Rio Manso?

3.LS4.D Biodiversity and Humans *Populations live in a variety of habitats, and change in those habitats affects the organisms living there.*

Start by looking at the changes in habitats in Rio Bravo due to flooding. Change was a normal part of this system: the river may change its channel and sweep away plants in one area, but leave its old channel as a wetland where other species will thrive.

Then contrast how humans cause changes to bosque habitats. Native organisms are less-well suited to these changes.

How do the human-caused changes to bosque habitats affect the organisms living there?

3.ESS3.B Natural Hazards *A variety of natural hazards result from natural processes. Humans cannot eliminate natural hazards but can take steps to reduce their impacts.*

Flooding is a natural part of the Rio Grande and floodplain ecosystems. Efforts to control flooding has allowed humans to settle in the floodplain, but has had negative impacts on natural ecosystems.

What type of natural hazard occurred along the river before humans made changes?

What effect does flooding have on the ecosystem and on the communities humans build along a river?

In what ways did humans reduce the impact of flooding on human settlements?

4.ESS2.A Earth Materials and Systems *Rainfall helps to shape the land and affects the types of living things found in a region. Water, ice, wind, living organisms, and gravity break rocks, soils, and sediments into smaller particles and move them around.*

Water plays an important role in creating floodplain ecosystems. Under natural conditions, the floodplain is constantly changing from the forces of river water. For example, the active channel moves, sandbars are created or washed away and sediment is deposited in the forest. These changes affect the organisms living there.

Look at the Changing River model with a view to the river channel, the sandbars and the physical valley; list the changes that occur both within each time period and between Rio Bravo, Rio Manso, and Rio Nuevo.

Along Rio Bravo, in what ways does water change habitats in the floodplain?

How do physical characteristics and organisms in floodplain ecosystems change as a result of floods along the river?

4.ESS3.B Natural Hazards *A variety of natural hazards result from natural processes. Humans cannot eliminate natural hazards (e.g., earthquakes, tsunamis, volcanic eruptions). Humans cannot eliminate the hazards but can take steps to reduce their impacts.*

Flooding is a natural part of the Rio Grande and floodplain ecosystems. Efforts to control flooding have allowed humans to settle in the floodplain, but have had negative impacts on natural ecosystems.

What type of natural hazard occurred along the river before humans made changes?

What effect does flooding have on the ecosystem and on the communities humans build along a river?

In what ways did humans reduce the impact of flooding on human settlements?

5.ESS3.C Human Impacts on Earth Systems *Human activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, ocean, air and even outer space. But individuals and communities are doing things to help protect Earth's resources and environments.*

Humans have made many changes to the river valley and the river channel, and these human alterations have changed the dynamic nature of the Rio Grande floodplain and altered many aspects of natural habitats (changing from Rio Bravo to Rio Manso). In Rio Nuevo, students learn how humans are able to make new changes that help restore some components of natural floodplain ecosystems.

What changes did humans make along the Rio Grande to promote agriculture and allow settlement along the floodplain?

How did those human alterations affect the bosque, and how could they be modified to allow a more natural, dynamic system?

What are the effects on native species from these human activities?

How can we decrease the number of species that are threatened or endangered?

New Mexico Specific Standards

Because these performance expectations are unique to New Mexico, we present the PEs as well as the supporting DCIs, CCCs and SEPs that can be addressed by the River of Change activities.

Performance Expectation

5-SS-1 NM. *Communicate information gathered from books, reliable media, or outside sources, that describes how a variety of scientists and engineers across New Mexico have improved existing technologies, developed new ones, or improved society through applications of science.*

DCI: 5.ETS2.A Interdependence of Science, Engineering, and Technology

-Advances in science offer new capabilities, new materials or new understanding of processes that can be applied through engineering to produce advances in technology.

-Advances in technology, in turn provide scientists with new capabilities to probe the natural world at larger or smaller scales; to record, manage and analyze data; and to model ever more complex systems with greater precision.

-In addition, engineers' efforts to develop or improve technologies often raise new questions for scientists' investigation.

After years of building structures in the Rio Grande and its floodplain with the goals of reducing flooding and delivering irrigation water, biologists began to see impacts on the bosque ecosystem that were not intended or expected. The cottonwood forest corridor of the river was getting old, with few seedlings growing to replace them. Fish species like the Rio Grande silvery minnow were not finding the shallow, muddy, backwater areas needed to lay their eggs and produce successful fry. Use any of the following ideas after completing the "Changing River" or "Who Lives Where?" activities to explore New Mexico scientists and engineers and how they are helping preserve the bosque into the future. Any of these assignments will address ELA standards.

- *What engineering efforts could help the Rio Grande silvery minnow?* For a case study, look at the Los Lunas Rio Grande Silvery Minnow Refugium, that has received awards for its engineering design.
- *What other science-based engineering efforts are being used for bosque restoration?* Read the "Bulldozers in the Bosque" essay in the River of Change chapter introduction for one example.
- Miles of jetty jacks were installed in the 1950s. *Are/were they working? What did they help? What drawbacks do they present?*
- "Drains" were built throughout the valley. Many people see drains and think they are the Rio Grande, but they are not. *What are they? Why were they built and what do they do?*
- There are different dams on the Rio Grande. They are built for different reasons and purposes. Research any of them, but two to consider are Cochiti and Angostura. *How are they the same? How are they different?*
- Bosque Ecosystem Monitoring Program (BEMP) has been researching the Rio Grande bosque for many years. Go to their website and look at the monthly data they collect. Some of their results have been published or posted. *How has this research, with data collected by school students, helped resource managers along the Rio Grande?*

CCC: Science is a Human Endeavor

Men and women from all cultures and backgrounds choose careers as scientists and engineers.

Most scientists and engineers work in teams.

Science affects everyday life.

Creativity and imagination are important to science.

CCC: Science is a Way of Knowing.

Science is both a body of knowledge and process that add new knowledge.

Science is a way of knowing that is used by many people.

SEPs: Obtaining, Evaluating & Communicating Information

New Mexico Gartersnake
observed in the Rio Grande bosque
Photograph by Brandon Bourassa

Rio Bravo Information Cards

Cottonwood Seedlings — "baby" cottonwoods
(Populus deltoides ssp. wislizeni)
Small cottonwood trees which have just started growing. Generally, seedling stems are less than 1 inch (2.5 centimeters) in diameter at 4.5 feet (1.35 meters) from ground level.
Habitat needs:
- bare, wet soil to germinate
- open areas where there is a lot of sunlight
- roots must stay in water as the water table drops throughout the summer
- grows near water, on sandbars, near river's edge

RIO BRAVO

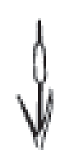
Cottonwood Saplings— "teenage" cottonwoods
(Populus deltoides ssp. wislizeni)
Small cottonwood trees. Larger than 1 inch (2.5 centimeters) in diameter and less than 4 inches (10 centimeters) in diameter at 4.5 feet (1.35 meters) above the ground level. Habitat needs:
- roots must reach to water as the water drops throughout the summer
- in former high water area—not far from riverbank
- not along the edge of river

RIO BRAVO

Big Cottonwood Trees— "mature" cottonwoods
(Populus deltoides ssp. wislizeni)
Mature Rio Grande cottonwood trees can be up to 80 feet (24 meters) tall with trunks up to 4 feet (1.2 meters) in diameter.
Habitat needs:
- usually not near current river channel (trees survived because the river changed location after the trees were established)
- in the flood plain, not on valley slopes
- roots must reach to permanent water table

RIO BRAVO

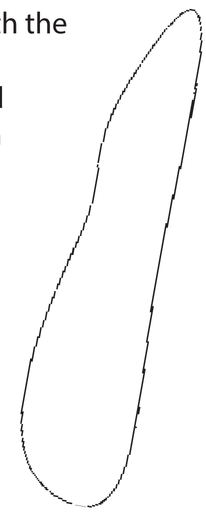
Cattails (*Typha* sp.)
These wetland plants represent marshes and are important areas for wildlife nesting, protection and food. Habitat needs:
- there must be water at the surface for most if not all of the year
- often at an oxbow—an old channel of the river
- occasionally on the edges of sandbars or the inside curve of meanders



RIO BRAVO

Rio Bravo Information Cards

Sandbars
Sandbars form in areas of the river where the water slows. Sediments, such as sand, drop out of the slowly moving river. Place:
• in the river channel or along the edge of the river
• lengthwise, with the flow of water
• the narrow end points upstream



RIO BRAVO

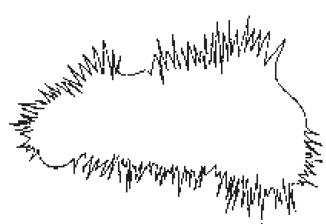
Upland Shrubs
Upland shrubs grow in dry places where the water table does not come near the surface. Habitat needs:
• live in higher areas
• depend on rain for moisture
• can live on very little water each year
Examples: fourwing saltbush, fringed sage, broom dalea/false indigo

RIO BRAVO

Native Riparian Shrubs
Native shrubs have lived here for thousands of years.
Habitat needs:
• in the flood plain of the river—the lowland alongside the river
• in the shade under old/mature cottonwoods
• sandbars
Examples: New Mexico privet/ New Mexico olive, silverleaf buffaloberry, coyote willow

RIO BRAVO

Grassy Meadows
Grasses belong to one of the largest families of plants, providing food (seeds, leaves, and roots) and shelter for many insects, rodents and birds.
• Different species grow in many environments from dry uplands to wet marshes, in full sunlight or in forest shade.
Examples: saltgrass, blue grama



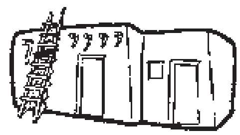
RIO BRAVO

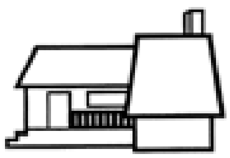
Rio Manso Information Cards

Houses

People moved into the area.

• place houses where you would want to live





RIO MANSO

Agricultural Fields

Include gardens, orchards, cropland and pastures.

• place in the flood plain of the river

• you may need to clear land for your crops

• orient long, narrow fields with the short side next to a ditch

RIO MANSO

Irrigation Ditches and Drains

Irrigation ditches and drains move water to agricultural fields and back to the river.

• place drains outside of and parallel to the levees

• irrigation ditches should run from the river to the fields

• remember that water flows downhill

RIO MANSO

Levees

A levee is a raised embankment running parallel to the river. This high berm keeps the river confined in high water and protects areas beyond from flooding.

• place parallel along the entire length of the river

• place on both sides of the river

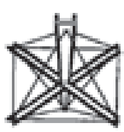
• narrow and straighten the river — confine it to a narrow channel

RIO MANSO

Rio Manso Information Cards

Jetty Jacks
These are giant metal frames the same shape as the pieces in the game of jacks—held together by thick cables. They were designed to protect the levees from being washed away by the river.
The river is narrowed and straightened by this process—confined to a narrower channel.
Place:

- some between the river and the levee, on both sides of the river
- some parallel to the river's edge
- some perpendicular to the levee, angling downstream



RIO MANSO

Exotic Riparian Trees
Non-native, exotic trees were brought here by people; most species were introduced in the last 100 years.

- place in the flood plain of the river—the lowland alongside the river
- may grow in the shade under big cottonwoods
- often grow in openings, such as after a fire

Examples: Russian olive, saltcedar or tamarisk, Siberian elm, tree of heaven

RIO MANSO

Snags / Downed Wood
Snags are standing dead trees. Many are created by fire. Most bosque fires are started by people, and fires have increased since humans settled in the area. Downed wood includes fallen branches and trees. Although they increase the risk of fire, snags and downed wood provide habitat for many animals.

- place in bosque between river and levee

RIO MANSO

Dam
Place a dam at the upper edge of the model

- it will cross from one edge of the flood plain to the other—from upland to upland across the river
- it will totally control the flow of the river—water will be released under specific conditions
- catastrophic flood will now be controlled—the spring runoff will be reduced and the summer flow will be increased as water held behind the dam in high flow will be released in times of lower flow

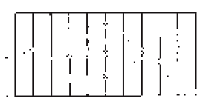
RIO MANSO

Rio Nuevo Information Card

Monitoring Plots

Resource managers need to monitor the results of their actions and monitor the bosque in general to understand what changes are happening:

- select sites where you want information about what is happening in the bosque
- select some sites that have not been disturbed
- select some sites where restoration projects are installed

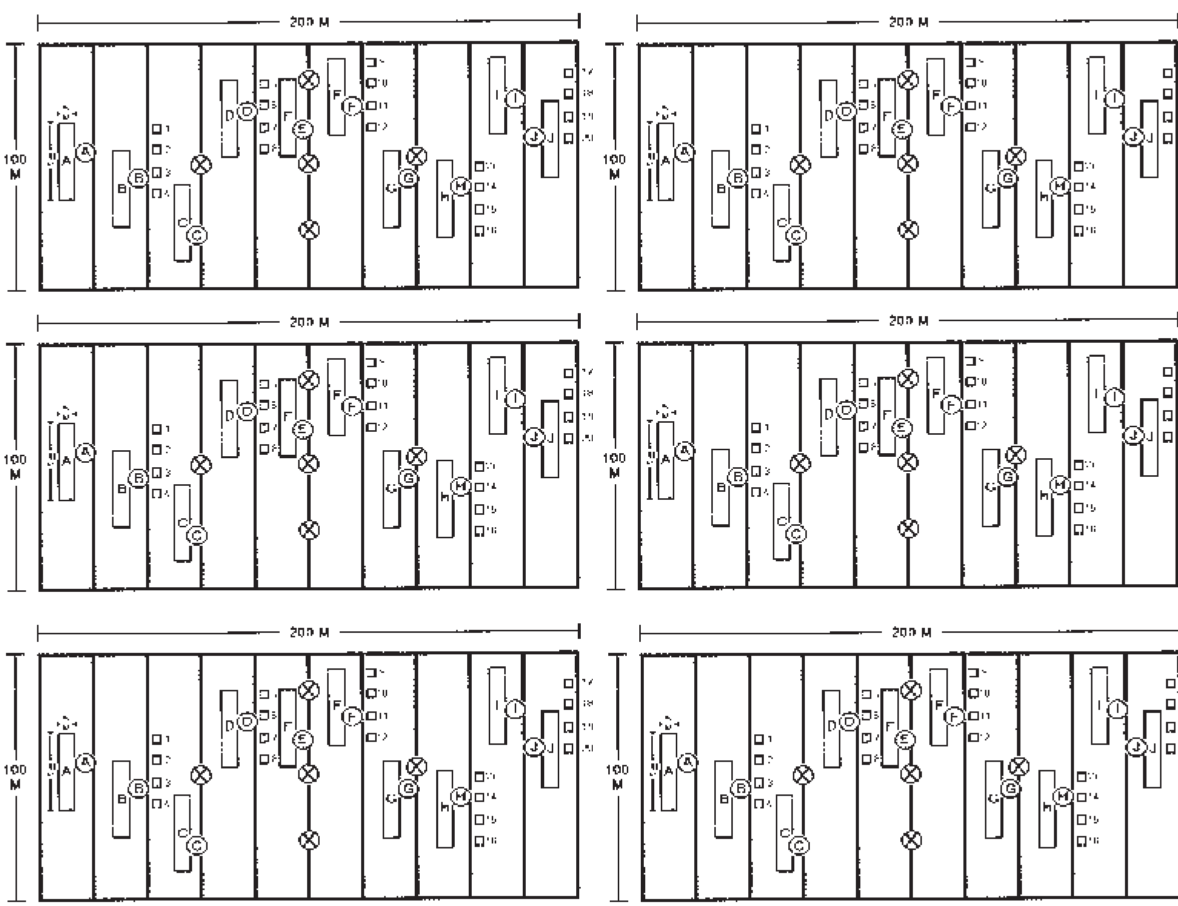


RIO NUEVO

About the monitoring icon:

The icon used to represent monitoring plots is a diagram of a study plot from the Bosque Ecosystem Monitoring Program (BEMP). BEMP is only one kind of monitoring study and other studies may have different designs. BEMP plots are 100 meters by 200 meters and are oriented lengthwise parallel to the river. Each plot contains 10 vegetation plots (the long rectangles), five groundwater wells (circle with an 'x'), 10 litterfall tubs (circle with letter), and 20 pitfall traps (small squares). The plots also have two rain gauges and three temperature data loggers, but these are not pictured on the icon.

Rio Nuevo Model Pieces **(make one copy and cut into six plots)**



Rio Nuevo Habitat Restoration Project Cards

Overbank Flooding

During years with a high winter snowpack there will be lots of water melting and flowing down the watershed in the spring. Much water will be held in reservoirs for irrigation through the summer, but in good years a large flow can be allowed downstream during the normal season for spring runoff. The water managers at the Army Corps of Engineers and Bureau of Reclamation can decide to allow for water amounts to pass through the dams that will spill over the banks of the river and flood some of the floodplain of the Rio Grande. This is called "overbank flooding." (The goal is to have standing water in wooded areas within the levees. This way the communities outside the levees are protected from flooding.) Overbank flooding creates habitat for cottonwood seedling establishment, increases the growth of mature cottonwoods and other native riparian plants as well as promoting the natural cycling of nutrients.

What beneficial changes will there be as the result of this project?
What habitat components can we replace on the model now?

- ✓ place 10 more cottonwood seedlings on the model; seedlings can be added to sandbars or edges of the river or to places that have been cleared of other vegetation
- ✓ place 2 more native riparian shrubs on the edges of the Rio Grande; plants such as willows will grow well now
- ✓ remove 1 upland shrub; wetter areas are no longer attracting upland plants
- ✓ if any homes have been placed within the levees, remove these now; floodplains are a silly place to build anyway
- ✓ remove 1 snag; with overbank flooding fuels are reduced by faster decomposition and less likely to burn with wetter conditions
- ✓ remove 1 exotic tree as conditions are not as optimal for some of these plants

Pole Planting of Cottonwoods

The numbers of cottonwoods are decreasing along the Rio Grande, because for decades flooding has been prevented and natural places for cottonwood establishment are not being created. One way to counteract this is to plant cottonwoods. Cottonwoods have an adaptation that land managers can take advantage of: a long, young branch of a cottonwood tree (here called a "pole") can be cut and put in the ground where it will send out roots and grow. We can have tall trees quickly, without needing to grow them in a nursery from seed. This usually takes a lot of labor, a giant drill to drill a hole down to the water table (remember cottonwoods need to have their roots in the water to survive), and very long branches of cottonwood, 15 - 20 feet long (5 - 6 meters) (and even then, all but a few feet will be buried). The cottonwood pole is slipped in the newly drilled hole and dirt is packed in. This is a way to give some cottonwoods a good start, but it is expensive, especially if you are looking at miles of river needing more cottonwoods.

What beneficial changes will there be as the result of this project?
What habitat components can we replace on the model now?

- ✓ add 10 more cottonwood saplings to the model, making sure you put them close to the river where the water table is not too deep
- ✓ add 1 more mature cottonwood tree to symbolize that this project will mean large trees in the future

Rio Nuevo Habitat Restoration Project Cards

Wetland Construction

The numbers of marshes and wetlands have been reduced over the last decades. Managers can create new ponds and wetlands. Some examples are the ponds at the Rio Grande Nature Center, at the Bosque del Apache National Wildlife Refuge, and southeast of the Alameda bridge over the Rio Grande in Albuquerque. A different type of wetland is a "constructed wetland" that takes wastewater and sends it through a series of small water pools. Each pool is filled with cattails and other plants that clean the water. Constructed wetlands can be found at Los Padillas Elementary School in Albuquerque, Sanchez Farm, Bernalillo County Open Space, and at Los Ranchos de Albuquerque village center.

What beneficial changes will there be as the result of this project?
What habitat components can we replace on the model now?

- ✓ place 50 more cattails on the model in groups representing 10 new constructed wetlands
- ✓ add 5 cottonwood seedlings (although wetlands are not specifically designed to recruit new cottonwoods, they often provide a good site for cottonwoods to reestablish)
- ✓ add 1 native riparian shrub; conditions are better for native plants such as willows
- ✓ remove 1 upland shrub; wetter areas are no longer attracting upland plants
- ✓ remove 1 exotic tree; conditions are not as good for some of these plants

Fuel-wood Reduction

In earlier years, the overbank flooding that would occur every few years would saturate the branches and leaves that had fallen on the ground in the bosque. By being wet, they would decompose more quickly than they have in recent decades. Microscopic organisms such as bacteria and fungi break down plant material into nutrients that can be used by other plants; this is called nutrient cycling. Prior to the regulation of the river, the cottonwood forest did not burn as hot as it does today—sometimes it was so wet that fuel wood on the ground decomposed fairly quickly. Since the elimination of overbank flooding after large dams were constructed on the river, fuel wood has built up on the floor of the cottonwood forests and everything is much drier. Fires spread very quickly once they get started and generally burn hotter and longer in the same area. Most fires are caused by careless people, and there are many more people living in the valley today. The fires burn far and wide. One way to reduce the destructiveness of fire in the bosque is to clean the area of downed trees and branches—reducing the fuels that create destructive fires. Teams of volunteers can haul away branches and sticks. Some snags and downed wood are left for wildlife habitat.

What beneficial changes will there be as the result of this project?
What habitat components can we replace on the model now?

- ✓ remove 4 snags; as we control the fuel in the forest, fires will be smaller and less severe. Some snags will be left for wildlife habitat.
- ✓ remove 5 exotic trees; many of the excess trees removed in these projects are non-natives
- ✓ add 1 native riparian shrub; while removing exotic and upland plants we are making room for native riparian shrubs
- ✓ add 1 grassy meadow; fuel breaks create more grasslands
- ✓ remove 1 mature cottonwood; sometimes we do need to cut some cottonwoods down to make an effective fuel break

Rio Nuevo Habitat Restoration Project Cards

Creation of Secondary Channels

The river used to have many channels as it flowed down the valley. Some would only have water in them during the spring runoff, but this was enough for cottonwoods to get a good start. In some areas, the easiest way for cottonwoods to get established is for us to help out nature a little. In places where the banks are just too high, managers can take in a bulldozer, lower the bank, and create a small side channel where water will flow some times of the year. Cottonwoods and native shrubs such as willow can get established here. Sediment removed from the banks can be returned to the river, creating new sandbars and improving Rio Grande silvery minnow habitat. Examples of this are on the west bank of the river south of Bridge Street in Albuquerque (the Albuquerque Overbank Project) and the silvery minnow channel near Rio Grande Nature Center State Park.

What beneficial changes will there be as the result of this project?
What habitat components can we replace on the model now?

- ✓ remove 3 jetty jacks; removal clears a path for the channel
- ✓ remove 1 exotic riparian tree
- ✓ add 40 cottonwood seedlings; these projects are prime habitat for germinating cottonwoods
- ✓ add 1 mature cottonwood tree to represent the future forest
- ✓ add 10 cattails to show more wetlands being developed
- ✓ add 2 sandbars below the project site, created by sediment moved by the earth work
- ✓ add 2 native riparian shrubs: birds like Southwestern Willow Flycatchers need thickets of willows to nest; these thickets have been rare for many years, and now more are being created
- ✓ remove 1 upland shrub because the habitat no longer provides the dry conditions these plants need

Removal of Exotic Species

Many agencies and landowners are involved in reducing the number of introduced species such as saltcedar (also known as tamarisk, *Tamarix chinensis*), Russian olive (*Elaeagnus angustifolia*) and Siberian elm (*Ulmus pumila*) in the bosque. These exotic shrubs and trees have increased, in general, because human-caused changes in the river valley provide favorable conditions for them to grow. Saltcedar thrived, especially in the lower Middle Rio Grande Valley. Saltcedar trees flower and produce seeds throughout the growing season; their reproduction is not restricted to spring/early summer as are native cottonwoods. When bare ground is colonized late in summer by saltcedar, it will not be bare in the spring when cottonwoods are sending out seeds. Both Russian olive and Siberian elm can sprout in shaded areas, under the canopy of the cottonwoods and are becoming very common in the bosque. Entire food chains depend on the cottonwood trees of the bosque. As cottonwoods are crowded out by introduced species such as these, the entire ecosystem is affected and fewer native species thrive.

Large saltcedar removal efforts have been undertaken at the Bosque del Apache National Wildlife Refuge. They have experimented with different procedures to effectively keep the saltcedar from returning. Santa Ana Pueblo has also undertaken major projects to restore the bosque to its previous native-species-only state. The bosque near Tingley Beach in Albuquerque is a showplace contrasting a restored area to the invaded area. This work can range from volunteers cutting down and removing exotic trees to the use of large equipment for bulldozing and repeated rootplowing, sometimes using herbicides to reduce their reoccurrence. Now tamarisk beetles are also helping to reduce saltcedar numbers. In some areas, saltcedar is left as habitat for endangered Southwestern Willow Flycatchers.

What beneficial changes will there be as the result of this project?
What habitat components can we replace on the model now?

- ✓ remove 10 exotic riparian trees; 11 are left to provide habitat
- ✓ add 2 grassy meadows; removing exotic species provides space for more grasslands
- ✓ add 1 mature cottonwood; exotic species are removed and there is room for our native trees

Rio Nuevo Habitat Restoration Project Cards

Water Conservation

The amount of water that is used by people along the river has an impact on the health of the bosque and river life. Pumping more water than is replenished through infiltration each year causes the water table to drop; plants that depend on groundwater can no longer reach their roots to that depth and die. When the water table is lowered, more river water will soak down into the ground, leaving less flow on the surface — less water for all of the users who need water. Some New Mexico communities use river water for their household water supply. The more water taken from the river, the less is available for the plants and animals that have evolved to depend on that water. Though some water will be returned to the river after passing through a sewage treatment facility, much is used, evaporates, or returns to groundwater. The City of Albuquerque had used only groundwater for its water supply for many decades, though they owned the rights to Rio Grande water, referred to as surface water. As the population increased and water use increased, the City now removes and cleans Rio Grande water and includes it in its water supply. Water is returned, but the flow level in the Rio Grande is reduced, affecting life below the pull-out area. We can lessen the need to lower the flow of the Rio Grande by reducing the water we use: plant low-water use landscaping, install rain barrels and low-flow toilets, turn off the water while brushing your teeth, take shorter showers, etc. Now that Albuquerque is using river water, the aquifer below the City is actually recharging.

What changes will there be as a result of this water conservation project?
What habitat components can we replace on the model now?

- ✓ add 5 cottonwood seedlings; with more water in the river, more places can flood and start new trees, and seedlings can be added to sandbars or edges of the river
- ✓ add 5 cattails; more water in the river means more wetlands

Jetty Jack Removal

The Kellner jetty jacks were placed up and down the river, starting in the 1950s, to straighten the river and protect the levees. The jacks slow the flow of water so that sediment drops out and builds up and eventually plants can grow. This helps keep the bank of the river in one place. The straighter and narrower channel helps the water flow downstream more quickly. The jacks also help to protect the levees. Today, the riverbanks and levees are quite stable. Now the jacks are seen as a danger to emergency vehicles moving through during a fire, possibly blocking escape routes. Several management agencies are removing jacks from the bosque. Managers now realize that a stable riverbank does not benefit the bosque; the river and its banks need to be able to move again. In addition to removing the jacks, managers can lower the riverbank in certain places to promote flooding and to restore sediment to the river. All of these may improve habitat for silvery minnows and other species.

What beneficial changes will there be as a result of this project?
What habitat components can we replace on the model now?

- ✓ remove 5 jetty jacks from the model
- ✓ remove 3 mature cottonwood trees as trees sometimes are removed in the process
- ✓ add 5 cottonwood seedlings as the river can meander more and create new sites for cottonwood regeneration
- ✓ add 3 cattails as the river can be more braided and provide more wetlands
- ✓ add 2 sandbars below the jetty jack removal project
- ✓ remove 1 exotic tree; exotic trees like Russian olive often grow within the jetty jacks and are removed with them

Monitoring

An important part of managing the bosque is to understand what is happening to the plants, animals, water table and other ecological functions in the bosque. The process of collecting, compiling, and analyzing information is called “monitoring.” Monitoring is an essential tool for land managers to understand if their actions are making any changes (good or bad) in the ecosystem. Many agencies responsible for caring for the river and the bosque collect data on a regular basis. Some schools also help collect important data. In addition to measuring the water table, weather factors, and soil factors, students also collect information about plants and animals.

Why is it important to collect information about the bosque over the long term?
How can this information be used to help manage the bosque?

- ✓ add 6 monitoring plots to the model. Carefully choose places you wish to monitor. You may want some sites that have not been disturbed by recent activities. You might also want some sites where you have done projects.

Note: The monitoring icon is an image of a Bosque Ecosystem Monitoring Program (BEMP) plot. These sites are scattered throughout the Middle Rio Grande Valley and are generally monitored by students from Grades 2–12.

BEMP students measuring depth to groundwater
Photograph by Lisa Ellis

How Long Ago?

Rio Manso Math Exercise

When	What	How long ago? This year minus:
1884	One of the worst floods in the history of the Rio Grande. Alameda Dike is started. Flood is kept out of Albuquerque's Old Town.	- 1884 =
1885	Alameda Dike is improved and flooding of New Town is prevented once again.	- 1885 =
1904	Water breaks through a dike. Los Ranchos area becomes a lake.	- 1904 =
1925	Standing water is drained and levees to control the river are being built.	- 1925 =
1941	Flood waters go over and through the levee. Last large crop of cottonwoods gets its start.	- 1941 =
1957	River is made to stay in one channel by levees, jetty jacks and natural boundaries.	- 1957 =
1975	Cochiti Dam is finished. No more serious floods are likely.	- 1975 =

Canada Geese on Rio Grande sandbars
Photograph by Mark Higgins

14. Cottonwood Creation

Description: Students learn about cottonwood seedling survival through two steps. In Part One students identify the conditions a cottonwood seed needs to germinate (start growing) by using cotton balls on the river model. In Part Two, students toss coins or dice to try to grow seedling roots fast enough to keep up with a lowering water table. Students realize that very few cottonwood seeds actually become trees and that altered river conditions are very limiting for cottonwood establishment. This activity delves into a specific example of a species and its survival—what allows a species to continue to exist in its location.

Materials:

- River model (see activity 13, “Changing River”)
- Cotton balls (ideally 200 to 600, usually sold in bags of 200 or 300
- A copy of Root Race (page 205) for each student (laminate for repeated use)
- Writing tool for Root Race page (erasable markers for laminated sheets); use two colors, one for roots, the other for water depth.
- Pennies (or dice, spinner, or other device to randomly determine 1 or 2, or 1, 2, or 3), one per student or student pair
- Optional: gather real cottonwood seeds to share with the class

14. Cottonwood Creation

Grades: 3–8

Time: two hours which can be divided into two or four sessions (two parts with old and new river models)

Subjects: science, math

Terms: *germinate, groundwater, hydrology, overbank flooding, seedling, water table*

New Mexico STEM Ready! / Next Generation Science Standards

NGSS DCIs and New Mexico State Performance Expectations

3.LS1.B Growth & Development of Organisms
3.LS2.C Ecosystem Dynamics, Functioning & Resilience
3.LS4.C Adaptation
3.LS4.D Biodiversity & Humans
4.LS1.A Structure & Function
5.ESS3.C Human Impacts on Earth Systems
MS.LS1.B Growth & Development of Organisms
MS.LS2.A Interdependent Relationships in Ecosystems
MS-LS2.C Ecosystem Dynamics, Functioning & Resilience
MS-LS4.B Natural Selection*
MS.ESS3.C (MS-ESS3-3 NM) Human Impacts on Earth Systems

NGSS CCCs

Patterns; Cause & Effect: Mechanism & Explanation; Scale, Proportion & Quantity; Systems & System Models*; Structure & Function

NGSS SEPs

Asking Questions & Defining Problems; Developing & Using Models; Analyzing & Interpreting Data

(* indicates extension activity)

Part One: Cottonwood Cotton Game—How Trees Get Started

Objective:

Students will explore how conditions impact the ability of cottonwood seeds to germinate (begin to grow).

Introduction:

Have students add to KWL charts—*What do they **Know**? What do they **Want** to know?* And then, *What have they **Learned**?* at the end of the activity. These questions will help drive the learning as they work through the lesson on the question:

What do you know about cottonwood trees? **(Asking Questions & Defining Problems)**

Students will model part of the life cycle of a plant—a cottonwood tree: Seeds need to land in the right conditions/locations, then the roots must grow fast enough to survive as the water level drops through the summer. **(Systems & System Models;** see Appendix K**)**

Procedure:

Section A: Rio Bravo

- Set up the river model to represent the old river (Rio Bravo). For guidelines, see activity, 13, "Changing River."
- Give each student a handful or two of cotton balls. Explain that each cotton ball represents a cottonwood seed.
- Ask students to describe the difference between true cotton and cottonwood seeds. (True cotton comes from an agricultural plant; cottonwood seeds are surrounded by a mass of fine threads that resemble cotton and allow the wind and water to transport the seeds away from the mother tree.)

- Have students stand around the sides of the river model. Standing with their backs to the center will have more random results. Tell the students that they will mimic the female cottonwood trees by tossing the cotton balls on the model at the same time. Since the seeds are transported by wind they will land at random locations. Ask students to toss their cotton balls into the air and onto the model on the count of three. Students may re-toss any that land off the model.
- Explain the conditions a cottonwood seed needs to germinate:
  - full sunlight (no shade)
  - bare soil
  - wet soil

In the old river these conditions occurred in areas that received overbank flooding, particularly where existing plants were scoured away by the spring floods.

- For this round, instruct students to collect all the cotton balls that:
  - landed on sandbars
  - are within one hand's length **(wrist to fingertips)** of the river edge
  - are not touching any other vegetation such as grass, shrubs, trees, or cattails (shade)
  - are not in the water (washed away)

  Place these in a "germinated" pile.

  Pick up all the other cotton balls and put those in a "did not germinate" pile.
- Have students count the number of cotton balls in each pile and write these numbers down (on the board or in their class journals). Discuss the difference in the size of the piles. The "germinate" pile should be smaller than the pile that did not germinate because there are fewer available sites for the seeds to start to grow. If the piles are equal or the "germinate" pile is larger, ask the students if they understood the directions and repeat these steps if necessary.

Rio Bravo Discussion Questions

Ask the students:

Where do cottonwoods survive well? Less well? Or not survive? **(3.LS4.C; Patterns)**

How do cottonwoods reproduce? What type of seeds do they have?

Why do you think cottonwood trees make so many seeds?

What do the seedlings need to get started growing (germinate)? **(3.LS1.B; MS.LS1.B)**

Consider different structures of the cottonwood tree (leaves, seeds, roots, etc.).

What adaptations/structures and functions help a cottonwood to survive, grow and reproduce?

How does a cottonwood change through the seasons and through its lifetime that helps it survive?

(4.LS1.A; 3.LS4.C; Structure & Function)

What role does a spring flood play in cottonwood generation? **(3.LS2.C; MS.LS2.C)**

- You may want to review the KWL charts to see what has been learned, and what students still want to know.

You may want to move to Part Two, Root Race, to determine the fate of the young seedlings before moving on to the Rio Manso section of the Cottonwood Cotton Game.

Section B: Rio Manso

- Change the river model to represent the altered river (Rio Manso). For guidelines, see the activity 13, "Changing River."
- Repeat Rio Bravo steps, handing out the same number of cotton balls.
- Explain to the students that in this changed river ecosystem, there is very limited overbank flooding. The only seeds that germinate will be
  - on bare sandbars
  - on the edge of water (rivers, ditches, drains, etc.) up to 1 inch (2.5 cm) **(~width of 2 fingers)** from the edge of the river.
  - are not touching any other vegetation such as grass, shrubs, trees, or cattails (shade)
  - are not in the water (washed away)

  Ask students to once again pick up the cotton balls from the model and make two piles, one for successfully germinated seeds and one for seeds that did not germinate.
- Count the piles and compare the results with the old river activity. There should be a significant reduction in the number of seeds that germinated.

Rio Manso Discussion Questions:

Ask the students, *Why did fewer seeds germinate?* Some answers may include: lack of flooding left fewer wet sites, straightening the river left less river edge, growth of exotic species and filling-in of the forest left fewer bare/unshaded patches, etc.

How have humans changed the river and the bosque? How have these changes affected cottonwoods?

(3.LS4.D; Scale, Proportion & Quantity)

The environment has changed.

Do cottonwoods survive well, move or die?

(3.LS2.C; Patterns; Cause & Effect)

- Move on to Part Two, Root Race, to determine the fate of the newly germinated seedlings.

Part Two: Root Race: How Seedlings' Roots Must Keep Up With the Lowering Water Table

Objective:

Students learn that a cottonwood seedling's roots must grow as fast or faster than the water table drops in order to survive by playing a game visually demonstrating water table levels and root growth.

Procedure:

Section A: Rio Bravo

- Explain to the students that once a cottonwood seed germinates, its next hurdle is to grow roots fast enough to keep up with the water table as it drops after the flood. Students will play the Root Race game for each of the cotton balls in the pile of successfully germinating seeds from the Cottonwood Cotton Game. First review the *Teacher's Example Form: Root Race* to show how the sheet works, then hand out the blank *Root Race* sheets.

  What is a big challenge for a growing seeding? **(3.LS1.B)**

- Each student or student pair will roll for a piece of cotton from the pile that **did** germinate in the old river.
- To start, set the water level even with ground level at the top of the chart. Explain that this represents the seasonal flood that corresponds with the release of seeds from the cottonwood trees.
- Have each student or student pair flip a coin. If heads, move root one increment down; if tails, move root two increments (or roll the dice—odd move one increment, even move two). Each increment will represent approximately four inches of soil depth.
- To determine how the water level moves each round, have one student flip a coin or roll a dice for the whole class. Explain that the water table may lower faster in some areas than others, but, generally, within a small area, the water table lowers at the same rate. Therefore, only one flip per round for all activity sheets is needed for the water table. If the coin is heads, move the water table down one increment; if tails, move the water table down two increments (or if using dice, odd move one increment, even move two increments).
- Any time the water level drops below the root, that seedling dies. Mark it as dead. If the root of the seedling reaches the bottom of the chart before the water table, mark it as "alive." Explain that the bottom of the chart represents the lowest level of the water table for that area.
- Repeat this process for all of the cotton pieces that germinated in Step 1 for the Rio Bravo. Count the number of seedlings that died and the number that lived, and record these on the board or in student journals.

- Discuss the difference between the number of seeds that reached the bottom of the chart and those that didn't. Based on this activity, *What chance did a germinated cottonwood seed have of surviving? What conditions did it need to survive this season? How were the seedlings affected by the underground water level?* **(3.LS1.B; 3.LS2.C; Analyzing & Interpreting Data)**

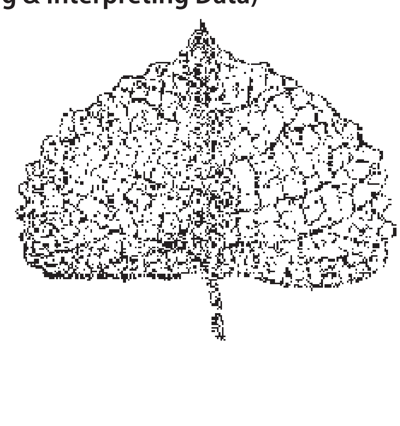
Section B: Rio Manso

- Have students play the Root Race game for each of the cotton balls in the pile of successfully germinating seeds from the Cottonwood Cotton Game. Explain that the "rules" have changed since the conditions along the river are different. Since the hydrology (the way water moves above and below ground) is different in the new river, explain that **the water table will drop by increments of one, two, or three,** but **seedling roots still grow in increments of one and two.**
- Now that the hydrology has been changed, the water table responds differently than it did with the old river. Humans have built dams, installed drains, drilled wells for homes and industry, and made other changes that have lowered groundwater levels, to the detriment of cottonwoods. When flipping for the water table, have students flip the coin twice. If they flip two heads, the water table drops one increment. If they flip one head and one tail, the water table drops two increments. If they flip two tails, the water table drops three increments. (With dice, a one or a two equals one increment, a three or a four equals two increments, and a five or six equals three increments.)
- Repeat the steps for all of the cotton pieces that germinated in the Rio Manso round as before. Count the number of seedlings that died and the number that lived, and record these on the board or in student journals.
- Lead a discussion on this activity.

In which environment did more cottonwoods get started?

In Rio Manso, young cottonwood trees are not being established in large enough numbers to replace older trees that die out.

Have students compare the results of established cottonwood seedlings between Rio Bravo and Rio Manso. How does this activity compare with the way cottonwood trees are really established? What other factors may affect cottonwood tree establishment?
(3.LS2.C; MS.LS2.A; Scale, Proportion & Quantity; Analyzing & Interpreting Data)



Section C: Rio Nuevo

- In the third river, Rio Nuevo, new management strategies have goals of bringing as many of the characteristics of the Rio Bravo as possible within the levees to today's river. This includes overbank flooding and creating conditions for cottonwoods to sprout and thrive (see Rio Nuevo discussion in "Changing River" activity).

In what ways have human-caused changes affected cottonwoods in the bosque?

How have various restoration projects impacted cottonwood establishment?

List the projects to improve cottonwood establishment and show these projects on the model.

In what ways can we help cottonwoods today?

(3.LS4.D; 5.ESS3.C; MS.ESS3.C)

Assessments:

- Return to the KWL charts created at the beginning of this lesson. *What have students **Learned**? What more do they **Want** to know?*
- Students should be able to explain what conditions are needed for cottonwoods to germinate and grow. Without the correct conditions, cottonwoods—a key species in the bosque—will not successfully grow. Human-caused changes in the bosque have made it harder for cottonwood seedlings to grow and many mature trees are dying. **(Cause & Effect)**
- Have students demonstrate their own learning about cottonwood's life cycle through graphic, written or other means. **(Developing & Using Models)**

Extensions:

- For a variation, the teacher may choose to have a "heavy summer rainfall" so the groundwater does not drop during one round.
- Graph all the results to help understand the differences. Calculate the percent of cottonwood seeds that survived and did not survive. Create bar graphs or pie charts to compare the number of seeds produced by a tree and those that find the right conditions to grow. Compare those that start growing (germinate) with those that survive through the summer. **(Analyzing & Interpreting Data)**
- Use the lens of a System to think through the Structure and Function and/or Adaptations of cottonwoods—the system of a cottonwood tree itself. (See Appendix K) **(3.LS4.C; 4.LS1.A; Systems & System Models; Structure & Function)**
- What factors would lead to some seedlings surviving and some not? Explore concepts like the genetic diversity of any species and how natural selection might affect survival of seedlings. **(MS.LS4.B)**

NGSS Connections to Cottonwood Creation - Disciplinary Core Ideas

[Middle School details in Appendix K]

3.LS1.B Growth and Development of Organisms *Reproduction is essential to the continued existence of every kind of organism. Plants and animals have unique and diverse life cycles.*

Cottonwood trees are very important to the bosque. In this activity, we focus on the conditions for germination and the needs of the growing cottonwood seedling.
How do cottonwoods reproduce? What type of seeds do they have?
What do they need to get started growing (germination)?
What is a big challenge for a growing seedling?
How does a cottonwood tree change through its lifetime?
How do cottonwoods change through the seasons? (flowers in spring, leaves only in warm months, turn yellow in fall—bringing nutrients back in for next year, no leaves in winter, buds in spring, etc…)

3.LS2.C Ecosystem Dynamics, Functioning and Resilience *When the environment changes in ways that affect a place's physical characteristics, temperature, or availability of resources, some organisms survive and reproduce, others move to new locations, yet others move into the transformed environment, and some die.*

This activity delves into a specific example of a species and its survival—what allows a species to survive in its location.

Rio Bravo: The river and bosque experienced annual and seasonal changes through spring runoff and the accompanying flood pulse.
What role does a spring flood play in cottonwood generation?
How does the river flow change during a year? (high water in spring, dropping through the summer)
How were the seedlings affected by the undergroundwater level?

Rio Manso: Human-caused changes to the physical characteristics of the river and bosque influence the availability of resources and necessary physical conditions, which in turn affects a seedling's survival. Humans have altered the amount of water, when and where it is present and physical characteristics of sandbars and riverbanks, all of which affect the availability of germination sites.

The number of seeds that find the right conditions to germinate will differ between Rio Bravo, Rio Manso and Rio Nuevo. *Have students predict what will happen in each time period—how and why have the conditions changed in each? and how does this affect the number of seeds that survive?*

3.LS4.C Adaptation *For any particular environment, some kinds of organisms survive well, some survive less well, and some cannot survive at all.*

The riparian ecosystem supports many more plant species than the arid uplands. Certain species are present only in one habitat or the other. Different plants are adapted to different environments.
What adaptations do cottonwoods have to help them survive in the bosque?
Where do cottonwoods survive well? Less well? Or not survive?

3.LS4.D Biodiversity and Humans *Populations live in a variety of habitats, and change in those habitats affects the organisms living there.*

Although floodplain ecosystems are very dynamic, with frequent changes to habitats occurring at a local scale, native organisms are less able to deal with the types of changes caused by humans. Prior to human changes, the diversity of species in New Mexican riparian habitats was very high. Changes in floodplain conditions have affected the number of cottonwoods able to germinate and survive in Rio Manso.
How have humans changed the environment of the bosque?
How have these changes affected cottonwoods? (fewer seeds germinate; drought can kill mature cottonwoods)

4.LS1.A Structure and Function *Plants and animals have both internal and external structures that serve various functions in growth, survival, behavior, and reproduction.*

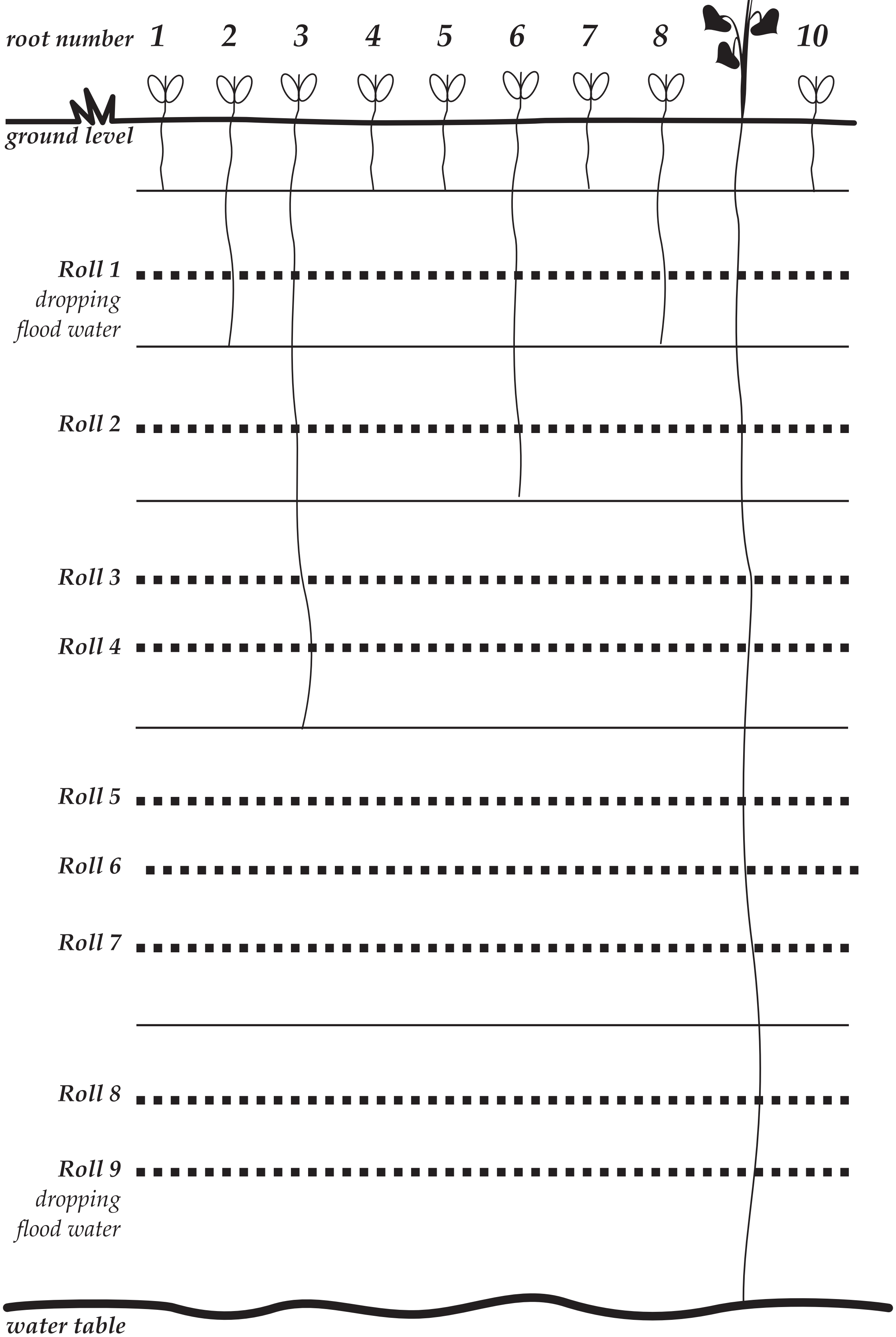
Plants have a variety of structures that allow them to survive in given habitats. Think about the cottonwoods and what structures help them to survive.
What structures do cottonwoods have to allow them to survive?
What helps them grow? What helps them reproduce?
Students can explore what cottonwood seeds look like, how they are dispersed, what parts of the tree get water and what parts get sunlight?

5.ESS3.C Human Impacts on Earth Systems *Human activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, ocean, air and even outer space. But individuals and communities are doing things to help protect Earth's resources and environments.*

Human activities have altered many features of the Rio Grande and its floodplain. Consider how the hydrological changes have affected cottonwoods that live there.
In what ways have humans caused changes in the bosque that affect cottonwoods?
In what ways can we help cottonwoods today? (Do Rio Nuevo section of Changing River model)

Teacher's Example: Root Race

This example is for the Rio Bravo. Dice rolls are for one or two. How many roots reach the water table before the spring flood dries up?



Root Race

How many roots will reach the water table before the spring flood dries up?

root number 1 2 3 4 5 6 7 8 9 10

ground level

water table

15. Who Lives Where?

Bosque Animals

Description: Students explore animals' niches in bosque habitats using the Changing River model and see how human-caused changes to the bosque impact the ability of animals to survive and thrive over time.

Objectives: Students will:

- explain structure and function/adaptations of animals surviving in the bosque;
- compare conditions for survival of animals in the past, present and optimal future of the bosque;
- analyze the results of human-caused changes to the bosque on native animals; and
- describe the effects of introduced/exotic animals on native animals.

Materials:

- Scissors to cut the pieces
- Envelopes or plastic sandwich bags to hold the pieces and information cards
- Who Lives Where? animal pictures and description cards
- "Changing River" activity materials for Rio Bravo, Rio Manso, and Rio Nuevo

15. Who Lives Where?

Grades: 2–12

Time: Material preparation: approximately 30 minutes
Activity: one 40-minute class period

Subjects: science

Terms: *adaptation, aquatic, barbels, breed, cavity, camouflage, carrion, colonize, detritus, disease, echolocation, endangered, extinct, gills, habitat, hectare, hibernate, introduced species, larva, meander, metamorphosis, non-native species, plague, predator, prey, raptor, scat, sonar, threatened, transparent, tributary, trilling*

New Mexico STEM Ready! / Next Generation Science Standards

NGSS DCIs and New Mexico State Performance Expectations

3.LS2.C Ecosystem Dynamics, Functioning & Resilience
3.LS2.D Social Interactions & Group Behavior *
3.LS4.C Adaptation
3.LS4.D Biodiversity & Humans
4. LS1.A Structure & Function
5.LS1.C Organization for Matter & Energy Flow in Organisms *
5.LS2.A Interdependent Relationships in Ecosystems *
5.ESS3.C Human Impacts on Earth Systems
5.ETS2.A (5-SS-1 NM) Science & Society
MS.LS1.B Growth & Development of Organisms
MS.LS2.A Interdependent Relationships in Ecosystems
MS.LS2.C Ecosystem Dynamics, Functioning & Resilience
MS.LS4.D Biodiversity & Humans
MS.ESS3.C (MS-ESS3-3 NM) Human Impacts

NGSS CCCs

Patterns; Cause & Effect: Mechanism & Explanation; Systems & System Models*; Energy & Matter: Flows, Cycles & Conservation; Structure & Function; Stability & Change; Cause & Effect: Mechanism & Explanation; Systems & System Models

NGSS SEPs

Asking Questions & Defining Problems; Developing & Using Models; Constructing Explanations & Designing Solutions; Engaging in Argument from Evidence; Obtaining, Evaluating & Communicating Information*

(* indicates extension activity)

Procedure:

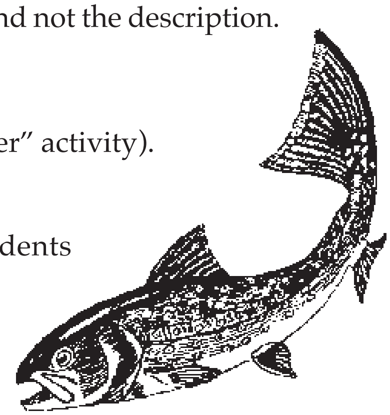
- Prior to the activities with students, cut out the animal pictures and information cards for each animal. Choose which of the animal description cards you will use—each animal has separate cards for older students and younger students (text for older students on top in a single-line box; text for younger students below in larger type with double-line box). The cards should be cut apart and may be colored. We recommend copying the Rio Bravo animals and descriptions on a different color paper than the Rio Manso animals. You may want to code the pictures and descriptions so they can be matched after being mixed up. (A list is included below.) It is best if the name of the animal appears only on the picture and not the description.

Section A: Rio Bravo

- Set up the river as Rio Bravo (see "Changing River" activity).

Introduction:

- Revisit the KWL charts, to consider what students already know about the animals that live along the river and in the bosque. *What do they **Know**? What do they **Want** to know?* And then, *What have they **Learned**?* at the end of the activity.



Ask students:

What animals live along the river or in the bosque?

What about the way the animal is built or the way it acts allows it to survive there?

(Asking Questions & Defining Problems)

Then follow Option A or Option B, below:

Option A

- Animal Match: Pull one pair of cards for every pair of students in the class. (20 students = 10 animals with both illustration and description cards for each animal) Each student gets either a picture or a description of one Rio Bravo animal.
- Challenge the students to find their "partner."

  Have the students take turns reading a description, with classmates guessing which animal is being described. The student with the matching drawing should place the animal on the model in the habitat described in the reading. Continue around the room until all the animal descriptions are read and all the drawings are placed on the model. Even better is to have students silently read the card, then in their own words tell the class about that animal.

Option B

- If you have less class time, hand out the animals with their description cards to the students. Each student should have at least one animal of his or her own with the accompanying description card. Have the student carefully read the description and decide where that animal lives. What is its habitat? Students should then place the animal on the bosque model in a location where it would best live. (Place them on the Rio Bravo bosque before placing the ditches, levees and homes.) Have each student describe his or her animal and where it lives to the entire group. Do another round with other animal cards, if appropriate.

Rio Bravo Discussion Questions:

Animals provide perfect examples of how an organism's shape and particular functions in the body help it to survive. Look for patterns of where animals are found in the river and floodplain and how their adaptations help them to survive there.

What do animals need to survive?

Are any particular structures more suited to life along the river or in the bosque?

Look for features that animals have that allow them to survive in their particular habitat and that might be shared by different species (e.g., something that helps them swim better, eat a particular food, etc.).

Think about growth, getting food and water, surviving predators or competitors, reproducing or enduring seasonal changes.

What structures or behaviors does each species have that help it to survive in these habitats?

(3.LS4.C; 4.LS1.A; MS.LS1.B; Patterns; Cause & Effect; Structure & Function)

Think about annual and seasonal changes to the river associated with spring runoff and the resulting flood pulse.

Which animals need high spring water flow?

Will animals move into areas newly changed by a flood? If so, which animals?

Will any animals move out of flooded or changed areas? If so, which animals?
(3.LS2.C; MS.LS2.C)

- Option: Do the "Bosque Chaos" activity on the model.

  How do the "Bosque Chaos" changes affect the animal species that live in the river or bosque?
  List ways species continue to thrive or are harmed in these changing conditions throughout the year. **(3.LS2.C; MS.LS2.C)**

Section B: Rio Manso

- Add the human alterations to the bosque model: irrigation ditches, levees, jetty jacks, etc. (Rio Manso).
- Place the introduced species on the model, using the method from Option A or Option B above. *Were any of the animals affected by the changes in the river associated with human activities or the introduced species of animals? Which animals are thriving because of the changes along the river and which have lost habitat?*
- Have the class review "Threatened and Endangered Animals" near the end of this activity—a brief summary of some threatened, endangered, or extinct bosque animals.

Rio Manso Discussion Questions:

Think about how human-caused changes affect the availability of resources, such as alterations to the river channel, loss of sandbar habitats, amount and temperature of the water (in the channel, overbank flooding, groundwater), and changes to the plants and wetland habitats that are thriving in the floodplain. These affect animal survival.

How do changes in habitats affect the animal species?

What effects do human activities have on native animals?

Look at the threatened and endangered species that live in the bosque.

What can our local community do to help protect threatened and endangered species?

Make a chart showing which animals are surviving well, which move away, which move in, and which have gone extinct following these human-caused changes; indicate which physical changes affected the animals.

Are there any structural or functional similarities among these different groups of species?
(3.LS2.C; 3.LS4.C; 3.LS4.D; 4.LS1.A; Patterns; Cause & Effect; Structure & Function; Stability & Change)

Think about introduced / exotic species.

What effects do these new species of plants or animals have on native species?

Do some of them affect how well other species of animals survive in the bosque?

What adaptations do these introduced animals have to allow them to thrive and out-compete some native animal species?

(3.LS4.C; 4.LS1.A; 5.LS2.A; MS.LS2.A; Structure & Function)

Section C: Rio Nuevo

Given that we have introduced species (bullfrogs, European Starlings, etc.), what choices can we make to minimize their effect and to maximize the success of native species? Have students brainstorm restoration ideas that will make habitats more suitable for native animals. Rio Nuevo Habitat Restoration Project Cards from "Changing River" can be used to stimulate discussion. Adjust the model pieces to reflect suggested changes (for example, remove exotic species, add in sandbars, add wetlands, etc.).

How do these restoration projects change the available habitat?

Are native animals helped by these changes? How so or why not?

Which animals are helped, and in what way are they helped?

(5.ESS3.C; MS.ESS3.C; Engaging in Argument from Evidence)

Assessments:

- Revisit the KWL charts. *What have they **Learned**? What else do students **Want** to know?* **(Asking Questions & Defining Problems)**
- Work in small groups. Model this bosque ecosystem as you understand it. Now take your model, and choose an animal to reduce (endangered) or add (non-native) to your bosque ecosystem. Based on changing that one component, model what happens to other parts of the ecosystem. Make a list of restoration projects that would help native biodiversity in your ecosystem.
    - Make a poster showing your resulting ideas. Have the class do a gallery walk of posters; each team should explain their main ideas to the class.
    - What additional questions do you have? Explore what students want to know based on their questions.

(Cause & Effect: Mechanism & Explanation; Systems & System Models; Asking Questions & Defining Problems; Developing & Using Models; Constructing Explanations & Designing Solutions)

Extensions:

- Animals provide an excellent path to understanding both matter and energy in ecosystems. Animals depend on plants not only for food and shelter but also for oxygen, which plants produce as a by-product of photosynthesis. Cottonwoods and other plants are important for providing the oxygen we all need to survive.

  How do animals get the energy and matter they need?

  How might energy or matter be transported into, out of or within an ecosystem (consider the activity of animals, decomposers, flooding, etc.)?

  Use the animal cards and plant cards from the "Who Grows Where?" activity to do "The Web" activity in this *Guide*; or to further understand the cycle of matter and flow of energy use the "Who Grows Where?" and "Who Lives Where?" cards in the "Energy in Bosque Ecosystems" activity in this *Guide*.

  (5.LS1.C; 5.LS2.A; MS.LS2.A; Energy & Matter; Systems & Systems Models; Developing & Using Models)
- Use the overview of threatened and endangered species and of introduced and non-native species at the end of this activity to further discuss the current situation in the bosque. *What animals are being, or have been, displaced by these introduced species?* Have students research more about either of these topics and present findings in a poster, written paper, oral report or other format. **(Obtaining, Evaluating & Communicating Information)**
- Oral history extension: send animal pictures home with students to ask elders about local names and stories about them. Have students report their findings back to the class. **(Obtaining, Evaluating & Communicating Information)**
- Focus on the animals that live in groups. *How does being in a group help those animals? Are they always in a group, or, if not, when are they in a group?* Some animals to look at are: Harvester ants, Western chorus frogs, Mallards, Canada Geese, Bald Eagles, Sandhill Cranes, Crows, Red-winged Blackbirds, European Starlings, House Sparrows, Coyotes, Mule deer, Elk, Feral dogs, and Rio Grande silvery minnows. **(3.LS2.D)**
- Have students research a particular species of animal to learn more about where it lives, what it needs to survive, etc. They could present this as a poster, written paper, or other format. **(Obtaining, Evaluating & Communicating Information)**

Who Lives Where? Rio Bravo

Common Name	Scientific Name
Mayfly	*Baetis* sp.
Field Cricket	*Gryllus* sp.
Floodplain Cicada	*Tibicen marginalis*
Caddisfly	*Hydropsyche* sp.
Harvester Ant	*Pogonomyrmex* sp.
Leaf-roller	*Anacampis innocuella*
Mosquito	many spp.
Shovelnose Sturgeon	*Scaphirhynchus platorynchus*
Rio Grande Bluntnose Shiner	*Notropis simus simus*
Red Shiner	*Cyprinella lutrensis*
Rio Grande Silvery Minnow	*Hybognathus amarus*
Western Chorus Frog	*Pseudacris triseriata*
Northern Leopard Frog	*Lithobates pipiens*
Western Painted Turtle	*Chrysemys picta*
Spiny Softshell Turtle	*Apalone spinifera*
New Mexico Whiptail	*Aspidoscelis neomexicanus*
Bullsnake	*Pituophis catenifer*
Gartersnake	*Thamnophis* sp.
Canada Goose	*Branta canadensis*
Mallard	*Anas platyrhynchos*
Greater Roadrunner	*Geococcyx californianus*
Yellow-billed Cuckoo	*Coccyzus americanus*
Sandhill Crane	*Grus canadensis*
Killdeer	*Charadrius vociferous*
Great Blue Heron	*Ardea herodias*
Cooper's Hawk	*Accipiter cooperii*
Bald Eagle	*Haliaeetus leucocephalus*
Great Horned Owl	*Bubo virginianus*
Belted Kingfisher	*Ceryle alcyon*
Southwestern Willow Flycatcher	*Empidonax traillii extimus*
American Crow	*Corvus brachyrhynchos*
Summer Tanager	*Piranga rubra*
Red-winged Blackbird	*Agelaius phoeniceus*
Desert Cottontail	*Sylvilagus audubonii*
Little Brown Bat	*Myotis lucifugus*
Beaver	*Castor canadensis*
Botta's Pocket Gopher	*Thomomys bottae*
New Mexico Meadow Jumping Mouse	*Zapus luteus luteus*
Muskrat	*Ondatra zibethicus*
White-footed Mouse	*Peromyscus leucopus*
North American Porcupine	*Erethizon dorsatum*
Coyote	*Canis latrans*
Mule Deer	*Odocoileus hemionus*

Who Lives Where? Rio Bravo: Upper Watershed Adaptations

Rio Grande Cutthroat Trout	*Oncorhynchus clarki virginalis*
Osprey	*Pandion haliaetus*
American Dipper	*Cinclus mexicanus*
Black Bear	*Ursus americanus*
Elk	*Cervus elaphus*

Who Lives Where? Rio Manso: Animals Introduced to the Middle Rio Grande Bosque

Isopods: Pillbug and Sowbug	*Armadillidium vulgare* and *Porcellio laevis*
Carp	*Cyprinus carpio*
Mosquitofish	*Gambusia affinis*
Bullfrog	*Rana catesbeiana*
European Starling	*Sturnus vulgaris*
House Sparrow	*Passer domesticus*
House Mouse	*Mus musculus*
Feral Dogs and Cats	*Canis lupus familiaris* and *Felis catus*

Who Lives Where? Rio Manso: Upper Watershed Adaptations: Introduced

Rainbow Trout	*Oncorhynchus mykiss*
Brown Trout	*Salmo trutta*

Coyote at Valle de Oro National Wildlife Refuge in the floodplain of the Rio Grande
Photograph by Laurel Ladwig

NGSS Connections to Who Lives Where? - Disciplinary Core Ideas

[Middle School details in Appendix K]

3.LS2.C Ecosystem Dynamics, Functioning, and Resilience *When the environment changes in ways that affect a place's physical characteristics, temperature, or availability of resources, some organisms survive and reproduce, others move to new locations, yet others move into the transformed environment, and some die.*

Rio Bravo: Think about annual and seasonal changes to the river associated with spring runoff and the resulting flood pulse. For example, the Rio Grande silvery minnow needs muddy backwater areas created during overbank flooding to reproduce.
Do any animals depend on high spring water flow? If so, which animals?
Will animals move into areas newly changed by a flood? If so, which animals?
Will any animals move out of flooded or changed areas? If so, which animals?

After "Bosque Chaos" activity on the model:
How do the "Bosque Chaos" changes affect the animal species that live in the river or bosque?
List ways species continue to thrive in these changing conditions throughout the year

Rio Manso:

Think about how human-caused changes affect the availability of resources, such as alterations to the river channel, loss of sandbar habitats, amount and temperature of the water (in the channel, overbank flooding, ground water) and changes to the plants and wetland habitats that are thriving in the floodplain. These affect animal survival. Examples are loss of areas with mature cottonwood and willow trees, which provide holes for cavity-nesting birds and extensive, dense canopy for Yellow-billed Cuckoos.

Make a chart showing which animals are surviving well, which move away, which move in, and which have gone extinct following these human-caused changes; indicate which physical changes affected the animals.

3.LS2.D Social Interactions and Group Behavior *Being part of a group helps animals obtain food, defend themselves, and cope with changes. Groups may serve different functions and vary dramatically in size.*

Focus on the animals that live in groups. *How does being in a group help those animals? Are they always in a group, or if not, when are they?* Some animals to look at are: Harvester ants, Rio Grande silvery minnows, Western chorus frogs, Mallards, Canada Geese, Bald Eagles, Sandhill Cranes, American Crows, Red-winged Blackbirds, European Starlings, House Sparrows, coyotes, mule deer, elk, feral dogs.

3.LS4.C Adaptation *For any particular environment, some kinds of organisms survive well, some survive less well, and some cannot survive at all.*

The riparian ecosystem supports many more animal species than the arid uplands, yet certain species are present only in one habitat or the other. Different animals are adapted to different environments.
What helps each animal survive in the bosque or in the river?
Are native species able to adapt to human-caused changes to the environment?

Think about introduced/exotic species. *What adaptations do these introduced animals have to allow them to thrive and out-compete some species of native animal?*

3.LS4.D Biodiversity and Humans *Populations live in a variety of habitats, and change in those habitats affects the organisms living there.*

Although floodplain ecosystems are very dynamic, with frequent changes to habitats occurring at a local scale, native organisms are less able to deal with the types of changes caused by humans. Prior to human changes, the diversity of species in New Mexican riparian habitats was very high. Changes in floodplain habitats have affected the types of animals living there.
What types of changes in floodplain habitats have affected the animals that live there?
How do these changes in floodplain habitats affect the animals that currently are or used to be found in the bosque?

4.LS1.A Structure and Function *Plants and animals have both internal and external structures that serve various functions in growth, survival, behavior, and reproduction.*

Animals have a variety of structures that allow them to survive in given habitats. Think about animals in the bosque and river and what structures help them to survive. Consider growing, getting food and water, surviving predators or competitors, reproducing and enduring seasonal changes.
What structures help each animal grow, survive and reproduce in the bosque or river?
Think of examples of internal and external structures that affect the behavior of an animal? *In what ways do these structures influence behavior?*

Killdeer
Photograph by Laurel Ladwig

5.LS1.C Organization for Matter and Energy Flow in Organisms *Food provides animals with the materials they need for body repair and growth and the energy they need to maintain body warmth and for motion.*

There is a large variety of animal species present along the river and floodplain, and these animals depend on a variety of foods for energy and materials needed by their bodies. All animals ultimately depend on plants for both energy and oxygen.
What does each animal consume? What eats it?

5.LS2.A Interdependent Relationships in Ecosystems *The food of almost any kind of animal can be traced back to plants. Organisms are related in food webs in which some animals eat plants for food and other animals eat the animals that eat plants. Some organisms, such as fungi and bacteria, break down dead organisms (both plants or plant parts and animals) and therefore operate as "decomposers." Decomposition eventually restores (recycles) some materials back to the soil. Organisms can survive only in environments in which their particular needs are met. A healthy ecosystem is one in which multiple species of different types are each able to meet their needs in a relatively stable web of life. Newly introduced species can damage the balance of an ecosystem.*

Think about this standard from the species perspective, and how the different species interact.
What does each animal consume? What eats it?
How are the animal species' needs met in the bosque ecosystem?
Are animal species affected by other animal species that are present? If so, how?

Note that a decomposer card is in the "Energy in a Bosque Ecosystem" activity.
What is the role of decomposers in the food web?
Do the Rio Manso model and place the introduced/exotic species.
What effects do these new species have on native species?
How many links to other native species can you discover?
What happens if some of these native species are no longer here?

5.ESS3.C Human Impacts on Earth Systems *Human activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, ocean, air and even outer space. But individuals and communities are doing things to help protect Earth's resources and environments.*

Human activities have altered many habitats along the Rio Grande and its floodplain. Look at the section on Threatened and Endangered Species and consider how the hydrological changes have affected habitats and how those changes affect the animals that live there.
Have human activities affected native animals? If so, how?

Look at the restoration projects discussed in the Rio Nuevo model.
Are any animals helped by these projects? If so, which animals are helped, and in what ways are they helped?

Sandhill Cranes dancing at
Valle de Oro National Wildlife Refuge
in the floodplain of the Rio Grande
Photograph by Laurel Ladwig

Who Lives Where? cards

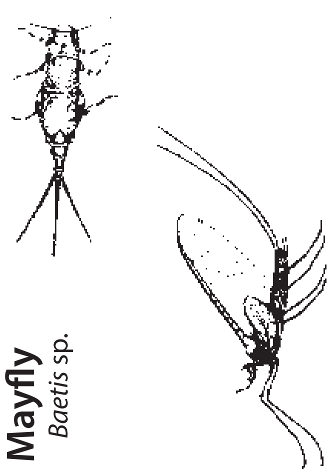
Part 1A: Rio Bravo: Animals Native to the Rio Grande Bosque

Text for older students top in single-line box, for younger students below in larger type in double-line box.

I have six legs and three tails. I spend most of my time under water in places where the sand moves around. I usually eat algae and detritus (dee-TRY-tus)—small pieces of dead plants or animals in the water. As an adult, I live for only a day or two and I don't eat. I attach my eggs to stones or other objects in the water. Many fish eat me, both when I'm young and as an adult. I am named for a month when I can often be seen.

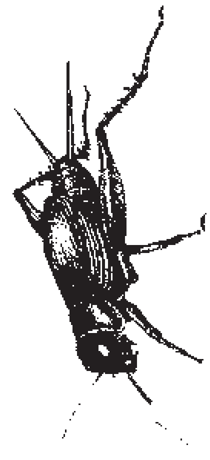
I have six legs and three tails. I live underwater in places where the sand moves around. I eat algae and small pieces of dead plants or animals in the water. As an adult, I only live for a day or two and I don't eat. I hook my eggs to stones or other things in the water. Many fish eat me. I am named for a month when I can often be seen.

Mayfly
Baetis sp.



I have large hind legs for hopping on the forest floor. My relatives and I mostly eat dead leaves or sometimes small insects. I prefer to live in areas that get flooded regularly, because the leaves are easier to chew. I "chirp" by rubbing my wings together to attract a mate—my song is very familiar on summer nights. My dark colors help me hide in the leaves. Lizards, birds and small mammals often eat me.

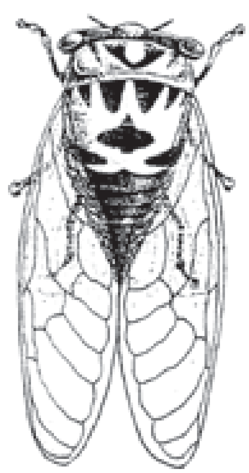
I have large hind legs for hopping on the forest floor. I eat dead leaves or, sometimes, small insects. I "chirp" by rubbing my wings together to attract a mate. My dark colors help me hide in the leaves. Lizards, birds and small mammals often eat me.



Field Cricket
Gryllus sp.

My buzzing call is part of summer. I lay my eggs on twigs in trees; they fall to the ground. My young go underground and suck the juice of plant roots for many months or years. One summer they climb out of the ground and crawl up a tree trunk. There they shed their skin and come out as adult flying insects with big bodies and transparent wings. Many different birds like to eat us.

My buzzing call is part of summer. After I lay my eggs on twigs in trees they fall to the ground. My young go underground and suck the juice of plant roots for many months or years. One summer they climb out of the ground and crawl up a tree trunk. There they shed their skin and come out as flying insects with big bodies and clear wings. Many birds like to eat us.



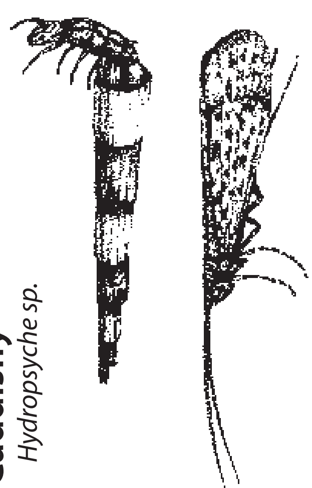
Floodplain Cicada
Tibicen marginalis

Rio Bravo

Harvester Ant
Pogonomyrmex sp.

I live with hundreds of my relatives in underground tunnels. We build a big mound above ground and clear away the plants around it. We live where the ground is dry with nearby grasses, amaranth and mustard plants that have seeds. Often small trails can be seen going out from the nest. We look for food along these trails. We collect small seeds and store them underground. Sometimes we also eat pillbugs that we sting and then carry below ground. We move our young around in the mound to warm or cool them as needed.

I live with lots of my relatives in underground tunnels. We build a big mound above ground and clear away the plants around it. We live where the ground is dry with nearby plants that have seeds. We collect seeds and store them underground. Sometimes we also eat pillbugs that we sting and then carry below ground. We move our young around in the mound to warm or cool them as needed.



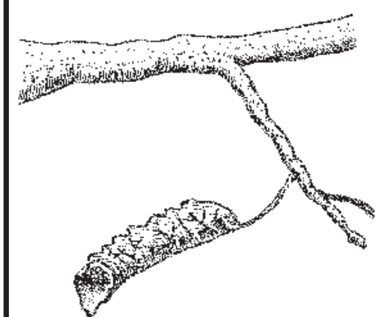
Caddisfly
Hydropsyche sp.

When I hatch from my egg I am a larva. I make a tube with tiny sticks or rocks for my home. I live on underwater gravel bars in fast-moving water where I catch my food. I eat algae, detritus (dee-TRY-tus) —small pieces of dead plants or animals—and small animals in the water. Fish love to eat me. As an adult, I have large wings to help me fly along the river.

After I hatch from my egg, I make a tube with tiny sticks or rocks for my home. I live in fast moving water where I catch my food. I eat algae, small pieces of plants or animals. Fish love to eat me. As an adult, I have large wings to help me fly along the river.

When I am young I am a caterpillar with a long body and I crawl around. I have strong jaws for chewing, so I can eat leaves of cottonwood trees. I also roll the leaves and tie them with silk. I hide inside and metamorphose. When I come out I am a moth. It's easy to find the rolled-up leaves on the ground after they fall out of the trees. Birds often eat me when I'm young.

Leaf-roller
Anacampis innocuella



When I am young I am a caterpillar. I eat leaves of cottonwood trees. I also roll the leaves and tie them with silk. I hide inside and change form—when I come out I am a moth. It's easy to find the rolled-up leaves on the ground after they fall out of the trees. Birds often eat me when I'm young.

I live in standing pools of water when I'm young. I have a breathing tube at my tail end, which I stick up through the surface of the water for air. I usually eat algae and detritus (dee-TRY-tus) — small pieces of dead plants or animals. As an adult, I fly around and my wings make a buzzing sound. I eat nectar and plant juices, but I need blood from an animal to be able to make my eggs which I lay in the water. Lots of birds and bats eat me.

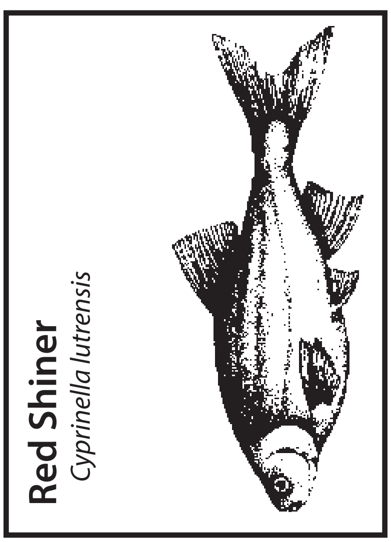
Mosquito
many spp.

I live in standing pools of water when I'm young. I eat algae and small pieces of dead plants or animals. As an adult, I fly around and my wings make a buzzing sound. I eat nectar and plant juices, but I need blood from an animal to be able to make my eggs. Then I lay my eggs in the water. Lots of birds and bats eat me.

Rio Bravo

I grow to three feet (1 meter) long with a slender body and have rows of bony plates on my back. My nose looks like a shovel. When I eat I stick my extendible mouth out into the bottom of the river. When I pull my mouth back in, I eat the larva of aquatic insects. I usually swim alone in the large channels of the Rio Grande. My young drift downstream, far down the river. When I am an adult, I attend a large family reunion, where all adults return upstream to the place we were born to lay or fertilize our eggs.

I grow to 3 feet (1 meter) long with a thin body and rows of bony plates on my back. My nose looks like a shovel. When I eat I stick my mouth out into the bottom of the river to catch food. I eat baby water insects. I usually swim alone. My young drift far down the river. I return upstream to the part of the river where I was born to lay or fertilize eggs.

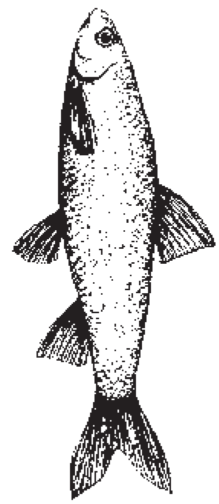


Most of the time my fins and scales are a dull color. My 3-inch (7.5-centimeter) body has an olive back, shiny sides and a white belly. However, when I am fertilizing eggs in spring and summer I have a red head and pink sides. Males of my species defend territories where we lay our eggs. I swim in the Rio Grande, where I prefer deeper, slower water. I eat small animals and plants, such as insects, crustaceans and algae.

Most of the time my fins and scales are a dull color. My 3-inch (7.5-centimeter) body has a dark green back, shiny sides and a white belly. However, when I am fertilizing eggs, I have a red head and pink sides. I swim in the slower water of the Rio Grande. I eat small plants and animals such as insects and algae.

I am a small, silvery animal with fins and scales. I have small eyes. I rarely get longer than 3.5 inches (9 centimeters). I hatched from a floating egg. I eat algae and tiny plant pieces I find floating in the water and on the gooey river bottom. Sometimes I eat old insect skins. I usually travel in large groups called "schools." I prefer slow-moving waters where the river meanders and braids. I release my eggs when the river flow increases during the early spring to summer.

I am a small, silver animal with fins and scales. I have small eyes. I don't get longer than 3.5 inches (9 centimeters). I hatch from a floating egg. I eat algae and pieces of plants and bugs I find floating in the water and on the gooey river bottom. I usually travel in large groups called "schools." I prefer slow moving waters where the river splits in shallow channels.

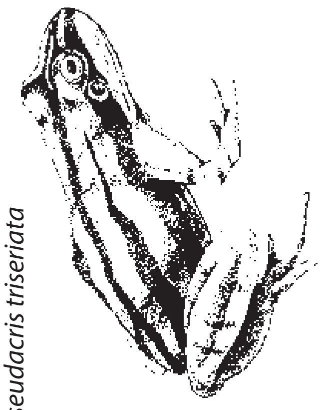


Rio Grande Silvery Minnow
Hybognathus amarus

I am a small, shiny animal with fins and scales. My back is pale greenish-brown, and I am about 3 inches (7.5 centimeters) long. I am most known for my flat face, well, it's really just my nose that's flat. I eat tiny plants, bugs, and plant pieces. I like to swim in the slow-moving parts of the river where the bottom is sandy and the water is no deeper than a foot (30 centimeters). The Rio Grande and its tributaries are my only home.

I am a small, shiny animal with fins and scales. My back is pale green-brown, and I am about 3 inches (7.5 centimeters) long. I am known for my flat nose. I eat tiny plants, bugs, and plant pieces. I like to swim in the river where the bottom is sandy and the water is shallow and slow. The Rio Grande and the rivers and streams flowing into it are my only home.

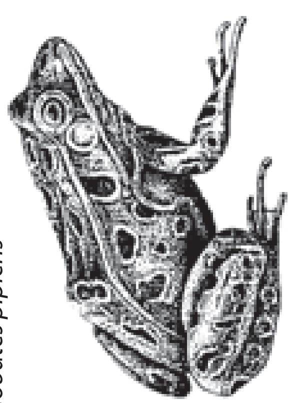
Rio Grande Bluntnose Shiner
Notropis simus simus



Western Chorus Frog
Pseudacris triseriata

I often sit at night on floating plants with my companions. Our voices join in a trilling song. When danger approaches, I quickly disappear underwater. When I was a tadpole, I lived underwater all the time. Then I ate plants, but as an adult I eat insects. My striped body helps me hide from turtles, birds and mammals. Fish eat my young. In the early spring and fall I am active during the day, but when it gets hot in the late spring and summer I come out at night.

I often sit at night on floating plants with my friends. Our voices join in a song. When danger comes close, I quickly hide underwater. When I was a tadpole, I lived underwater all the time. Then I ate plants, but as an adult I eat insects. My striped body helps me hide from turtles, birds and mammals. Fish eat my young.



Northern Leopard Frog
Lithobates pipiens

I live near standing water where I can keep my smooth skin wet. I have a fast tongue for catching flying insects. My long legs help me jump away from turtles and birds that want to eat me. My name comes from the spots on my skin. When I was a young tadpole, I used gills to help me breathe underwater but now I have lungs and can live on the shore. I lay my eggs in the water, attached to plants or to the bottom.

I live near still water where I can keep my smooth skin wet. I have a fast tongue for catching flying insects. My long legs help me jump away from turtles and birds that want to eat me. My name comes from the spots on my skin. When I was a young tadpole I used gills to help me breath underwater but now I have lungs and can live on the shore.

Most of my body stays hidden inside my hard shell. When I am threatened, I also pull in my striped head and legs. I like areas with quiet water, a soft bottom and lots of water plants. In the winter, I stay in mud under water. When it's warm I climb onto mudbanks, logs or rocks to sun myself. Often many of my friends and I share a log to bask. I eat insects, spiders, earthworms, mollusks, crayfish, fish, frogs and tadpoles. As I get older I eat more aquatic plants.

Western Painted Turtle
Chrysemys picta

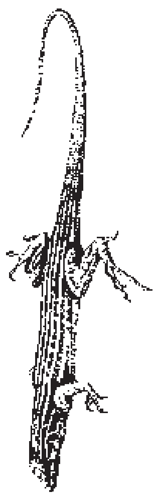
Most of my body stays hidden inside my hard shell. When I am afraid, I pull in my striped head and legs. I like areas with quiet water, a soft bottom and lots of plants. In the winter, I stay in mud under water. When it's warm I like to lie in the sun. I eat insects, spiders, earthworms, mollusks, crayfish, fish, frogs and tadpoles. As I get older I eat more water plants.

My shell can bend, and it is covered with a leathery skin. My arms, legs and body are flat and my toes are webbed, which helps me swim well. I have a long nose which I stick out of the water for air. I eat earthworms, snails, crayfish, insects, fish, frogs, tadpoles, and some aquatic plants. I like to stay in the river in areas with a sandy bottom and strong currents. On sunny days I like to bask on the riverbank or on logs. I am very fast on land and in the water.

Spiny Softshell Turtle
Apalone spinifera

My shell can bend, and it is covered with a tough skin. My arms, legs and body are flat and my toes are webbed, which helps me swim well. I have a long nose that I stick out of the water for air. I eat earthworms, snails, crayfish, insects, fish, frogs, tadpoles, and some aquatic plants. I like to stay in the river in areas with a sandy bottom and strong currents.

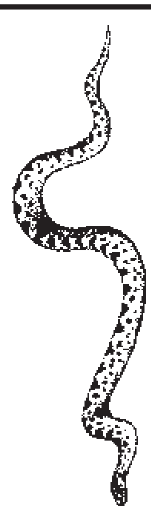
New Mexico Whiptail
Aspidoscelis neomexicanus



I move very fast on my four legs. I have stripes and light spots along my back. My tail is bright blue when I am young but changes to gray with a gray-green tip when I am grown. I like dry, open areas where I can sit out in the sun. I also seek shade under big trees and shrubs. I sleep through the cold winter. I eat insects and spiders. Roadrunners and other birds like to eat me. I have only sisters, because there are no males of my species. My young hatch from eggs.

I move very fast on my four legs. I have stripes and spots along my back. My tail is bright blue when I am young. Later it is gray. I like dry, open areas where I can sit out in the sun. I also look for shade under big trees and shrubs. I sleep through the cold winter. I eat insects and spiders. Roadrunners and other birds like to eat me. I only have sisters, because there are no males of my kind.

Bullsnake
Pituophis catenifer



I have a long, slender body with brown and black patches. When disturbed, I shake my tail in leaves on the ground and sound like a rattlesnake. But I do not have a rattle and I am not poisonous. I like to eat mice, rats, eggs, lizards and small birds. I am a constrictor. I squeeze my prey, and then I swallow my food whole. I can even eat prey bigger than my head. I hunt all through the bosque and surrounding uplands. My young hatch from eggs during the summer.

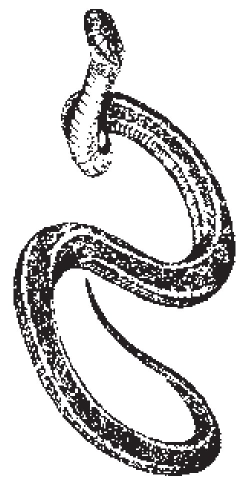
I have a long, slender body with brown and black patches. When upset, I shake my tail in leaves on the ground and sound like a rattlesnake. But I do not have a rattle and I am not poisonous. I like to eat mice, rats, eggs, lizards and small birds. I squeeze my prey, and then I swallow my food whole. I hunt all through the bosque and beyond.

I am a reptile without any legs or arms. I have a long yellowish-white stripe down my back. I eat fish, frogs, toads, tadpoles, lizards and worms. I can dislocate my jaw to open my mouth very wide for large prey. I swim well, but usually I slide along the moist ground under plants. Herons, roadrunners and some mammals try to catch me. If I get caught, I can release a stinky material to scare off the predator. My young do not hatch from eggs—they are born live.

I am a reptile without any legs or arms. I have a long yellow-white stripe down my back. I eat fish, frogs, toads, tadpoles, lizards and worms. I can open my mouth very wide to eat. I swim well, but usually I slide along the wet ground under plants. Herons, roadrunners and some mammals try to catch me.

Gartersnake

Thamnophis sp.



My long neck is dark and I have a white cheek patch, while my body is mostly brownish. My markings help me blend in with the marsh in winter. I am known for my loud "ahonk-ahonk" while I fly in a V-formation with thousands of my kind. I winter in the wetlands where I eat aquatic plants, grasses and some insects and crustaceans. Some of us breed in New Mexico while others head north in the summer. I form a bond with my mate and we breed when we are two or three years old. When our young get a bit older you can see us paddling along with them behind us.

My long neck is dark and I have a white cheek patch. My body is mostly brownish. My markings help me blend in with the marsh in winter. I am known for my loud "ahonk-ahonk" while I fly with my friends. I winter in the wetlands of the Rio Grande watershed. I eat aquatic plants, grasses and some insects and crustaceans. Some of us breed in New Mexico while others head north in the summer.

Canada Goose

Branta canadensis

Rio Bravo

Mallard
Anas platyrhynchos

My webbed toes make me a great swimmer but I can also fly to find other places with water. My tail sticks up out of the water when I dip my head below the surface to get food. I have ridges along my bill that let me strain aquatic plants, grass and small insects from the water. I build my nest on the shore. When they hatch, my chicks follow me in a line. Coyotes may try to eat me and raccoons and bullsnakes often eat my eggs.

My webbed toes make me a great swimmer, but I can also fly. When I dip my head below the water to get food, my tail sticks up. I have ridges along my bill so I can strain plants and insects from the water. I build my nest on the shore; when my chicks hatch, they follow me in a line. Coyotes may try to eat me and raccoons and bullsnakes often eat my eggs.

Greater Roadrunner
Geococcyx californianus

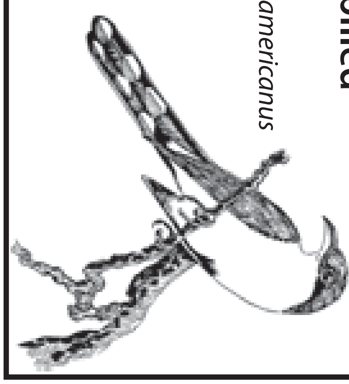
I have sturdy legs, a bushy crest and a long tail. My feathers are streaked, shaggy brown. I can fly but I like to run. My favorite foods are lizards and snakes but I also eat insects, rodents and birds. I hunt in open areas but I build my nest in a low tree or thicket. My husband generally sits on the nest. My mate and I stay together all year. I sing a slow song of low-pitched coos.

I have strong legs, a bushy head and a long tail. I can fly but I like to run. My favorite foods are lizards and snakes, but I also eat insects, mice, and birds. I hunt in open areas but I build my nest in a low tree or thicket. My husband generally sits on the nest. My mate and I stay together all year.

My back is grayish-brown, my belly is white, my wings are rufous, and I have white spots underneath my long, dark tail. I have a yellow lower bill. My favorite food is hairy caterpillars, but I also eat other insects, lizards, berries and fruit. I look for food in dense, leafy trees and shrubs. I often breed where there are cicadas, tent caterpillars or other large insects. I typically need large patches of mature riparian woodland with lots of cover to breed. I build my nest of twigs in mature willows. I spend summers in New Mexico and other parts of the U.S., but I fly to South America for the winter.

Yellow-billed Cuckoo

Coccyzus americanus



My back is grayish-brown, my belly is white and my wings are reddish-brown. I have big white spots under my long, dark tail. My lower bill is yellow. My favorite food is hairy caterpillars. I also eat other insects, lizards, berries and fruit. I need large areas of big trees to build my nest. I build it of twigs in big willows. I spend summers in New Mexico and other parts of the United States. In winter I fly to South America.

I have a long neck and long legs. My feathers are mostly gray, although sometimes there are rust colored feathers on my back and sides. Red feathers top my head. I live near wetlands along the Rio Grande in the winter. We hang out in large groups in open fields and meadows. We eat whatever we can find, especially insects, small animals and plant parts. In the summer we fly north to breed. When we are nesting, my partner and I sing and dance together. My family flies back to the wintering grounds in the fall.

Sandhill Crane

Grus canadensis

I have a long neck and long legs. Red feathers top my head, but I am mostly gray and rust. In the winter I live near wet areas along the Rio Grande. My friends and I like to be in large fields. We eat insects, small animals, and plant parts. In the summer we fly north to breed. My partner and I like to dance together.

Killdeer
Charadrius vociferous

My name is my call. I have two black rings around my neck, brown feathers on my back and a white belly. I run quickly on slender legs along sandbars and riverbanks. I pick up insects, small water animals or plant parts from the surface of the sand or soil. I lay my camouflaged eggs in a depression on the ground among stones and gravel. If a predator comes near my nest, I pretend to have a broken wing to lure it away.

My name is my call. I have two black rings around my neck. I run quickly on skinny legs along the riverbanks. I pick up insects, small water animals or plant parts from the top of the sand or soil. I lay my eggs hidden by their spotted markings on the ground with stones and gravel. If a predator comes near my nest I pretend to have a broken wing to lead it away.

Great Blue Heron
Ardea herodias

I use my long legs to wade in the water. Blue-gray feathers cover most of my body, with black on my head. I stand patiently waiting for food to come close. With lightning speed I catch fish, frogs, crayfish, and even mice or gophers, using my large spear-like bill. My long neck helps me grab my prey. I hunt during the day and I usually stay near shore or where there are plants, because that's where my food tends to be. I like to hunt alone, but I build my large nest high in cottonwoods with several others of my kind.

I use my long legs to wade in the water. I stand very still waiting for food to come close. I catch fish, frogs, crayfish, and even mice or gophers using my large pointed bill. My long neck helps me grab my prey. I hunt during the day and I stay near shore or where there are plants, because that's where my food tends to be.

I am a raptor, which means I have sharp talons (claws) for catching prey and a hooked beak to tear meat. I have a long tail with dark and light brown bands. I hunt during the day. When I am hungry, I wait on a branch for a small bird to fly by. Then I dash after it, using my binocular vision to skillfully fly around the trees. I also eat small rodents, lizards and rabbits. I build my nest of sticks in the fork of a big cottonwood.

I have sharp claws for catching prey and a hooked beak to tear meat. I have a long tail with dark and light brown bands. I hunt during the day. When I am hungry, I wait on a branch for a small bird to fly by. Then I dart after it, and fly around the trees. I also eat other small animals. I build my nest of sticks in the fork of a big cottonwood.

Cooper's Hawk
Accipiter cooperii

As an adult, I have a dark brown body with a white head and tail. My massive beak is yellow and I have bare yellow legs. When I am young, my whole body is mostly dark brown with blotchy white underneath. As an adult female my wingspan can reach 8 feet (2.4 meters) while as an adult male it is 6 feet (1.8 meters). My wintering grounds include New Mexico, both along the Middle Rio Grande Valley and the upper reaches of the Rio Grande watershed. I go north to breed. I eat mainly fish that I capture with my huge talons, but I also eat carrion (dead animals). We nest in trees or on cliffs.

As an adult, I have a dark brown body with a white head and tail. My large beak is yellow and I have bare yellow legs. When I am young, my whole body is mostly dark brown mixed with white. I live in New Mexico in the winter. I live along the Middle Rio Grande Valley and in the upper watershed. I go north to breed. I eat mainly fish that I capture with my claws. I also eat dead animals.

Bald Eagle
Haliaeetus leucocephalus

Rio Bravo

Great Horned Owl

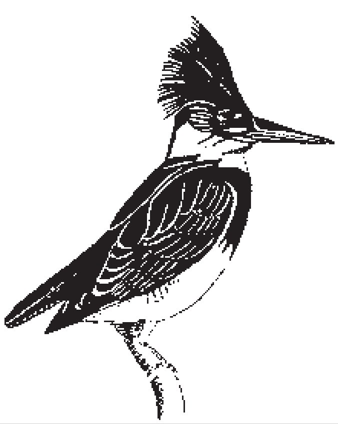
Bubo virginianus

My large eyes help me see well as I hunt at night for mice. My soft feathers help me fly quietly to sneak up on my prey. Some feathers on my head look like horns. During the day I hide in large trees where my feathers match the bark. I often use the old nest of a hawk or crow, or make a nest in a cave or a hole in a tree. My young hatch out during the cold winter but they don't leave the nest until spring.

My large eyes help me see well as I hunt at night for mice. My soft feathers help me fly quietly to sneak up on my prey. Some feathers on my head look like horns. During the day I hide in large trees where the color of my feathers matches the bark. My babies hatch during the cold winter but they don't leave the nest until spring.

Belted Kingfisher

Ceryle alcyon



I can be recognized by my rattling call as I fly along rivers and streams. I have a large head with a heavy bill. My back has bluish gray feathers and my belly is white. I have a bluish breastband if I am a male and two breastbands—one bluish and one rust—if I am a female. I live up to my name because I have excellent fishing skills. I dive head-first into the water to catch fish. I also eat frogs, lizards, insects, mice and even young birds. If you look along the riverbanks, you may find my burrow that I dig using my bill. I teach my young how to fish by dropping dead meals into the water for them to retrieve.

I can be recognized by my rattling call as I fly along the rivers and streams of New Mexico. I have a large, bushy head with a heavy bill. My back has bluish gray feathers and my belly is white with one or two stripes on my chest. I dive head first into the water to catch fish. I also eat frogs, lizards, insects, mice and even young birds. I dig a burrow into a riverbank using my bill.

I perch upright, scanning for insects flying over nearby water. Small feathers around my bill look like whiskers and help me catch flying insects. My back is a brownish color and each of my dark wings has two light stripes on it. I live in dense willow thickets where I build my cup-like nest in the fork of a small tree. I breed in New Mexico but I fly south for the winter.

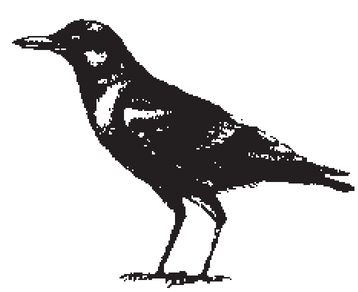
I sit up straight looking for insects flying over nearby water. Small feathers around my bill look like whiskers and help me catch insects. My back is a brownish color and I have two light stripes on my wings. I live in thick willow patches where I build my cup-like nest in the fork of a small tree. I nest in New Mexico but I fly south for the winter

Southwestern Willow Flycatcher
Empidonax traillii extimus

I am all black with a big straight beak. My caw caw warns my companions of danger and tells them where to find food. I use different calls to tell my friends different things. We gather together to feed in the bosque during the winter. We eat anything, including animals and plants. At night, we roost together in big flocks in the trees. In the summer most of us head north to build our nests, although some of us stay in the valley to breed.

I am all black with a big straight beak. My caw caw warns my friends of danger and tells them where to find food. We gather together to feed in the bosque during the winter. We eat anything, including animals and plants. At night, we roost together in big flocks in the trees. In the summer most of us head north to build our nests.

American Crow
Corvus brachyrhynchos



Summer Tanager

Piranga rubra

In the summer I dart about in mature cottonwood trees. I am covered with rosy-red feathers. I like New Mexico summers because there are plenty of insects to feed my young. I like to eat bees and wasps as well as fruit. We build our cup-like nests in trees that grow near water. By the time cold weather comes, my young are grown. We all fly south to Mexico or South America where it is warm in the winter.

In the summer I dart about in big cottonwood trees. I am covered with red feathers. I like New Mexico summers because there are plenty of insects to feed my young. I like to eat bees and wasps as well as fruit. By the time cold weather comes, my young are grown. We all fly south to Mexico or South America where it is warm in the winter.

Red-winged Blackbird

Agelaius phoeniceus

I show the bright red patches in my black wings as I sing loudly from the tops of cattails. My song keeps other males of my kind away from my territory. My wife is dark brown with lots of streaking. We build our nests above the water using stalks of marsh plants. I catch insects to feed my chicks. I travel around in large flocks to search for seeds in winter. Raccoons and some birds eat my eggs, and hawks may try to catch me when I'm older.

I show the bright red patches in my black wings as I sing loudly from the tops of cattails. I build my nest above the water in the cattails. I catch insects to feed my chicks. I travel around in large flocks to search for seeds in winter. Raccoons and other birds often eat my eggs, and hawks may try to catch me when I'm older.

I have long ears and a short furry tail. When predators like coyotes or hawks are nearby I may freeze or I may use my big feet to hop away. I like to eat grasses in meadows or in open patches in the forest. I am often out during the day, but I prefer to eat at night. I line my nest with fur from my belly. My babies are born with no fur, and their eyes and ears are closed. They grow quickly and can leave the nest after 14 or 15 days. I may have three or four litters a year.

I have long ears and a short furry tail. When coyotes or hawks are nearby, I may freeze or I may use my big feet to hop away. I like to eat grass in meadows or in the forest. I prefer to eat at night, but I am often out during the day. I line my nest with fur from my belly. My babies are born with no fur and closed eyes and ears.

Desert Cottontail

Sylvilagus auduboni

I have dark brown fur and a broad flat tail. My webbed feet make me a great swimmer. My favorite food is cambium (CAM-bee-um), the inner bark of cottonwood and willow trees, but I may also eat buds and fruits. I use my huge front teeth to cut down trees. I prefer young trees but I can cut big ones, too—then I cut off the branches to eat. My family shares a den in the bank of the river. Usually four to eight of my family members live together. We are most active at night. Coyotes, foxes, bobcats and mountain lions occasionally try to catch us.

I have dark brown fur and a big, flat tail. My webbed feet make me a great swimmer. My favorite food is the inner bark of cottonwood and willow trees but I may also eat buds and fruits. I use my huge front teeth to cut down trees. I dig a den in the bank of the river. I am most active at night. Coyotes, foxes, mountain lion and bobcats try to catch me.

American Beaver

Castor canadensis

Botta's Pocket Gopher
Thomomys bottae

My tail, ears and fur are very short. My eyes are small. My front legs are very strong. The claws on my front feet are very long. All of these adaptations help me dig and live underground. I burrow in deep, sandy soil where the trees aren't too close together. I push the soil that I dig out of my tunnels up to the surface and leave it in piles on the ground. My cheeks have fur-lined pockets to carry my food. I eat plant roots and occasionally a whole plant. Sometimes a coyote or badger will try to dig me out of my burrow.

My tail, ears and fur are very short. My eyes are small. My front legs are very strong. The claws on my front feet are very long. These things help me dig and live underground. I dig in deep, sandy soil where the trees aren't too close together. I eat plant roots. I have fur-lined pockets in my cheeks to carry my food. Sometimes a coyote or badger will try to dig me out of my burrow.

New Mexico Meadow Jumping Mouse
Zapus luteus luteus

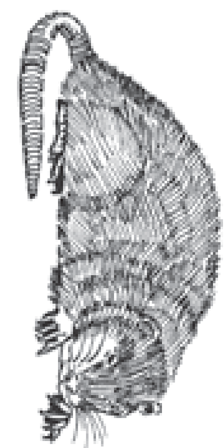
I jump like a frog with my long hind feet but I have fur and a tail. My fur is brownish on my back, yellowish on my sides, and white on my belly. I like to stay among wet grasses and under willows. My family lives around marshes. I mostly eat the flowers and seeds of grasses and other plants as well as insects. I hibernate for half the year, living entirely on fat stored in my body. Coyotes, snakes, hawks and owls try to eat me. When a predator, or something else, startles me, I take several long jumps, but then I try to hide again.

I jump like a frog with my long hind feet and tail, but I have fur. I like to stay in wet grasses and under willows. My family lives around marshes. I eat the flowers and seeds of grasses and other plants as well as insects. I hibernate for half the year, living entirely on fat stored in my body. Coyotes, snakes, hawks and owls try to eat me.

I'm smaller than a beaver, and my ribbon-like tail is flattened side to side. I have sleek brown fur. I swim in the river or in a pond and I'm most active at night. When looking for food I can stay under water as long as 20 minutes, but I don't usually stay down that long. I eat aquatic plants, as well as crayfish, fish and other small animals. I make a burrow in the riverbank. I usually live alone unless I have babies. I defend my home territory against others of my kind. Raccoons often eat my young.

I'm smaller than a beaver, and my ribbon-like tail is flattened sideways. I have smooth brown fur. I swim in the river or in a pond. I am most active at night. I make a burrow in the riverbank. I eat plants, as well as crayfish, fish and other small animals. I live alone unless I have babies. Raccoons often eat my young.

Muskrat
Ondatra zibethicus



I am small with grayish or orange-brown fur on my back and sides and a white belly and feet. I am the most common mammal in the bosque. I hide in the day and hunt for food at night. Climbing trees and shrubs is easy for me. I eat insects during the spring and summer, and seeds during the fall and winter. I store nuts and seeds in the fall to eat during the winter. Snakes, coyotes and owls often eat me. My nest is always in a hidden place, maybe a bird's nest, empty burrow or clump of grass.

I am small and brown with white belly fur and feet. I hide in the day and hunt for food at night. Climbing trees and shrubs is easy for me. I eat insects during the spring and summer, and seeds during the fall and winter. Snakes, coyotes and owls often eat me. My nest is always in a hidden place, maybe a bird's nest, empty burrow or clump of grass.

White-footed Mouse
Peromyscus leucopus

North American Porcupine
Erethizon dorsatum

I live in trees and in brush piles. You might think I'm a bird's nest. I have sharp quills all over my body that I use to protect myself from coyotes and great horned owls. When upset I show off the warning coloration of my black and white quills, then flick my tail towards whatever is scaring me. I eat cottonwood trees, nibbling off the buds and bark from stems then throwing these "nip twigs" onto the ground. My long claws and strong tail help me climb tall trees. I have big orange incisors (in-SY-zors), or front teeth, that help me eat the inner bark of trees called cambium (CAM-bee-um).

I live in trees. You might think I'm a bird's nest. I have sharp quills all over my body that I use to protect myself from coyotes and great horned owls. When upset I flick my tail towards whatever is scaring me. I eat cottonwood tree inner bark and buds. My long claws and strong tail help me climb tall trees with ease. I have big orange teeth that help me chew on my woody food.

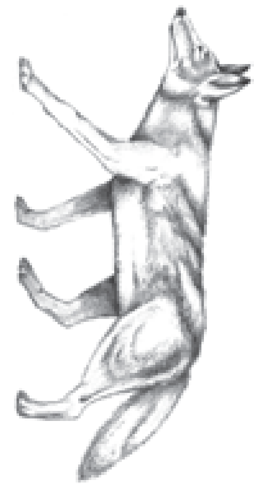
Little Brown Bat
Myotis lucifugus

I have wings but I am not a bird. My body is covered with brown fur. I use echolocation (sonar) to catch flying insects like mosquitoes. I skim over streams and ponds at night. During the day I sleep in hollow trees or under bark. When we have our babies, I gather with lots of my friends in sheltered areas like caves or cavities of trees. Sometimes I carry my baby with me as I hunt, but we usually leave them together at the roost. I hibernate during the winter.

I have wings but I am not a bird. I have brown fur. I catch flying insects like mosquitoes. I skim over streams and ponds at night. During the day I sleep in hollow trees. When we have our babies, I get together with lots of my friends in sheltered areas like caves or holes in trees. I hibernate during the winter.

I have a bushy tail, four slender legs, pointed ears that stand up and a sandy brown fur coat. In the mornings and evenings I yip and howl with my family. I eat whatever I can find, including mice, jackrabbits, ducks and other birds, berries and insects. I roam across many miles of the bosque and surrounding fields. Once in a while, I catch a roadrunner. I make a den in a sheltered place like an old animal burrow or a hollow log. My pups stay there for two to three weeks. After six to nine months they may go off on their own, or they may stay with me and my mate until the next year.

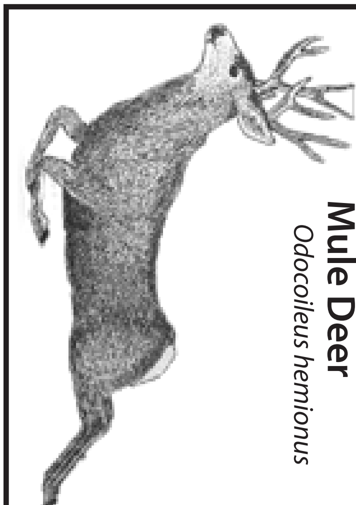
I have a bushy tail, four skinny legs, pointed ears that stand up, and a sandy brown fur coat. In the mornings and evenings I yip and howl with my family. I eat whatever I can find, including mice, jackrabbits, ducks and other birds, berries and insects. I roam across many miles of the bosque, and surrounding fields. Once in a while, I catch a roadrunner.



Coyote
Canis latrans

My summer coat is reddish but changes to blue-gray in winter and I have a whitish rump patch with a black-tipped tail. My ears are quite large! Males have antlers. I travel from lowland river bottoms to canyons and forested high country. I am most active in the morning, evening and on moonlit nights. I eat leaves, stems and buds of woody plants plus grasses and weeds. I have good eyesight, hearing and sense of smell. These help protect me from predators such as coyotes, mountain lions and bears. When our fawns are born they lie still to hide from predators.

My summer coat is reddish but my fur changes to blue-gray in winter. I have a whitish rump patch with a black-tipped tail and large ears. Males have antlers. I travel from river bottoms to canyons and mountain forests. I eat leaves, stems and buds of woody plants plus grasses and weeds. I have very good eyesight, hearing and sense of smell. Coyotes, mountain lions and bears try to eat me.



Mule Deer
Odocoileus hemionus

Who Lives Where? cards

Part 1B: Rio Bravo: Upper Watershed Adaptations: Native

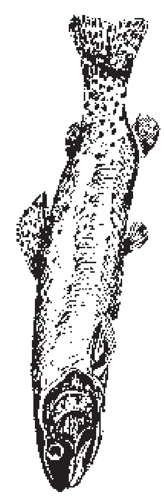
Text for older students top in single-line box, for younger students below in larger type in double-line box.

The following cards are for use with the model set up as Rio Bravo, but for upper watershed locations (upper tributaries or areas north of the Middle Rio Grande Valley). Use these if your school is located in the upper watershed or if you want to study the upper watershed.

My yellowish-green to gray-brown body is covered with scales and peppered with black spots. During breeding season the male’s belly becomes flaming reddish-orange. I am named for the reddish-orange slash in folds on either side of my lower jaw. I mostly live in headwater streams as I prefer cold, fast-moving waters. I eat aquatic insects and insects that land on the water. As an adult I may also eat small fish. My species was once found in all major watersheds on both sides of the Continental Divide and we were the only species of our kind in many New Mexico waters.

My yellow-green to gray-brown body has black spots. I am covered with scales. Males of my species have a belly that turns reddish-orange. I am named for a reddish-orange slash on the sides of my lower jaw. I mostly live in small, cold streams. I eat water insects and small fish. My species was once the only one of our kind in many New Mexico waters. I lay my eggs from March through July.

Rio Grande Cutthroat Trout
Oncorhynchus clarki virginalis



I have long, narrow wings with dark patches at the "wrists," a dark back, a white underside and a dark stripe through my eyes. I hover high above lakes watching for fish. I can fold my wings and plunge feet-first to scoop up a fish. The best time to see me above New Mexico waters is during spring as I travel north to breed and again in the fall when I fly to southern lands for the winter. I usually mate for life, and my husband fishes for me while I incubate our eggs. As a parent, I am kept very busy fishing for my young. Each chick can eat six pounds (2.7 kg) of fish a day!

I have long, narrow wings with dark patches at the "wrists." My back is dark and I have a white belly and a dark stripe through my eyes. I hover above lakes watching for fish. I am great at catching fish. The best time to see me in New Mexico is in the spring as I travel north to breed and again in the fall when I fly south for the winter. My mate helps catch fish for our young.

Osprey

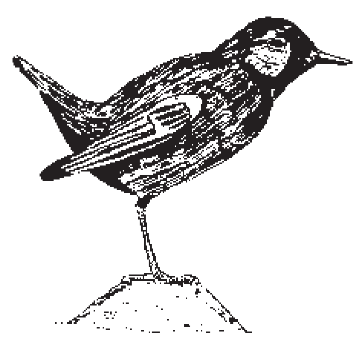
Pandion haliaetus

I am small but chunky with slate-colored feathers. Most often I hang out along rushing mountain streams of the upper watershed. I walk along the bottom as I search for caddisfly larvae and other aquatic insects. Sometimes I become completely submerged and I "fly" underwater using my powerful wings. I can even do this in water that is rushing too fast for you to stand in! I have very large oil glands and soft, dense feathers to help keep my body dry. I build my nests behind waterfalls or on rocks in the middle of the stream. You may see me bobbing as I wade and look for aquatic snacks.

I am small but chunky with slate-colored feathers. I hang out along fast mountain streams of the upper watershed. I walk along the bottom as I search for water insects. Sometimes I go all the way underwater and I "fly" using my strong wings. I have large oil glands and soft, dense feathers to help keep my body dry. I build my nests behind waterfalls or on rocks in the middle of the stream.

American Dipper

Cinclus mexicanus



Rio Bravo

Black Bear
Ursus americanus

My fur can be black, brown, cinnamon, or blond. As an adult male, I can weigh 250 pounds (113 kg) and as a female I am usually around 150 to 180 pounds (65–80 kg). I like to eat berries, rosehips, nuts, insects and honey. I can smell food from a long distance. I usually stay in the mountains, but I also visit lowland streams and river valleys to look for food, or when young are moving to find their own territories. In the winter, I go into a deep sleep, although I may wake up some from time to time. My cubs are born when I am in my winter den. They stay with me through the next winter.

My fur can be black, brown, cinnamon, or blond. I like to eat berries, rosehips, nuts, insects and honey. I can smell food from a long distance. I usually stay in the mountains, but I also visit lowland streams and river valleys to look for food. In the winter, I go into a deep sleep, although I may wake up some from time to time. My cubs are born when I am in my winter den.

Elk
Cervus elaphus

When I am born, I have a white-spotted fur coat and lie still in tall grass to keep predators from seeing me. I weigh 30 to 40 pounds (13–18 kg). I grow up to 1,000 pounds (450 kg) if I am a male and up to 600 pounds (270 kg) if I am female. My adult body is reddish-brown with a short white tail. The males of my species, called bulls, grow huge racks of antlers and are famous for the bugle call used as an advertisement, a battle cry and a mating call. I feed on grasses and enjoy browsing on riparian willows as I migrate from mountain meadows to lowland river valleys.

When I am just born, I have a white-spotted fur coat. I lie very still in tall grass to keep predators from seeing me. My adult body is reddish-brown with a short white tail. The males of my species grow huge antlers and use their bugle call as a battle cry and a mating call. I feed on grasses. I also eat river willows as I migrate from mountain meadows to lowland river valleys.

Who Lives Where? cards

Part 2A: Rio Manso: Animals Introduced to the Middle Rio Grande Bosque

Text for older students top in single-line box, for younger students below in larger type in double-line box.

The following cards are for use with the model set up as Rio Manso, the tamed river. These are animals that did not evolve in this area, but have been introduced into this ecosystem, both intentionally and accidentally. Often, introduced species out-compete native species, especially when the natural environment has been altered. The river is like an island for the natural species that live there—a long narrow island. They cannot live far from the wet riparian environment.

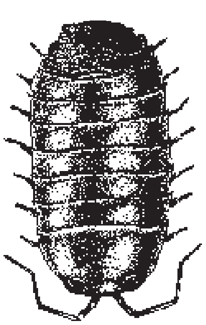
In this restricted area, introduced species and habitat destruction have a great impact. By destroying habitat, the narrow bosque area is cut into smaller pieces that support fewer and fewer native species.

I have 14 legs! I may roll into a ball to protect myself. I live on the forest floor among the leaves as crickets do. I eat dead leaves, leaving behind the "skeleton" of the leaf. Sometimes I eat animal scat (that's the word biologists use for "poop"!). Harvester ants may catch me, kill me, and carry me down into their burrow. Other small animals may eat me too. We arrived in the U.S. as unplanned cargo in ships from Europe and have spread here, taking over the role crickets had.

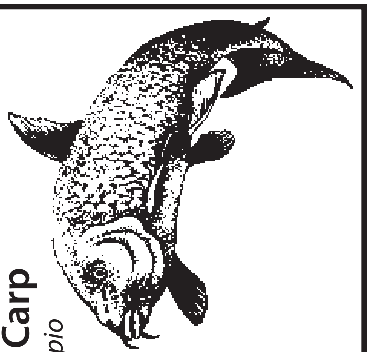
I have 14 legs! I may roll into a ball to protect myself. I live on the forest floor. I eat dead leaves, and sometimes I eat animal scat (that's a word for "poop"!). Harvester ants may catch me, kill me, and carry me down into their burrow. The ants may leave pieces of my white shell near their mound. Other small animals may eat me, too.

Isopods

Armadillidium vulgare (pillbug) and *Porcellio laevis* (sowbug)



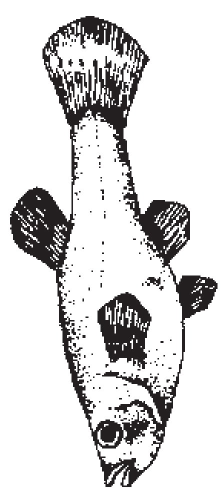
Rio Manso



Common Carp
Cyprinus carpio

I am a fish that people in the United States do not usually eat. I came to New Mexico in 1883. I enjoy quiet, warm water but I can live in almost any kind of water. I often change the habitat by uprooting plants, making the water muddy, and eating the eggs of other fish. I spoil the habitat for native fish. I have barbels that look like whiskers. Some people think I am a pest.

I am a fish that people here do not usually eat. I enjoy quiet, warm water but I can live in almost any kind of water. I often change the habitat by pulling plants, making the water muddy and eating the eggs of other fish. I spoil the habitat for native fish. It looks like I have whiskers. Some people think I am a pest.



Mosquitofish
Gambusia affinis

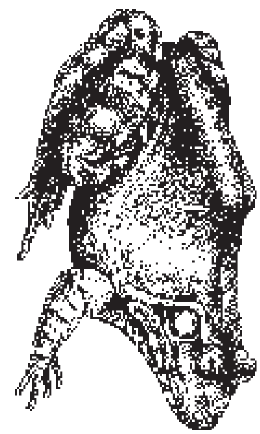
Look for me in warm, shallow water with many plants. I am 2 inches (5 centimeters) long and my mate is only 1 inch (2.5 centimeters). I am native to the lower Rio Grande but was introduced to the Middle Rio Grande because I eat mosquito larvae. My babies are born alive. I also eat other insect larvae, algae, crustaceans, and fish fry (baby fish). Because I eat fish fry, I sometimes kill off the fish that were in the streams and rivers before I came.

Look for me in warm, shallow water with many plants. I am 2 inches (5 centimeters) long and my mate is only 1 inch (2.5 centimeters). I am native to the lower Rio Grande, but was introduced to the Middle Rio Grande because I eat mosquito larvae. My babies are born live. I also eat other insect larvae, algae and baby fish.

I am the biggest frog in North America. I didn't always live in the Rio Grande Valley. I was brought here because my legs are so good to eat. I live in still waters of marshes or ponds where native frogs once ruled. I eat insects and any animal small enough for me to swallow, including ducklings. I need two summers to grow from an egg to a tadpole and on to a full-grown frog.

I am the biggest frog in North America. I didn't always live in the Rio Grande Valley. I was brought here because my legs are so good to eat. I live in marshes or ponds where native frogs once ruled. I eat insects and any animal small enough for me to swallow, including ducklings. I need two summers to grow from egg to tadpole and on to a full-grown frog.

Bullfrog
Rana catesbeiana



In the fall my black feathers are tipped with white and tan, but in the breeding season my plumage is iridescent black. I have a stocky body and a short, square tail. I can make lots of different sounds and imitate the songs of other species. I eat insects and other invertebrates, fruits and seeds. My ancestors came from Europe, but people took some of them to New York in 1890-91. Soon we spread across the U.S. We can live in many places. We nest in holes and often out-compete native species for nesting sites because we are aggressive and there are many of us.

In the fall my black feathers are tipped with white and tan. They show many colors in the breeding season. I have a stocky body and a short, square tail. I eat insects, fruits and seeds. My kind originally came from Europe. We like many types of habitats. We nest in holes. We take many of the nesting sites so native species can't use them. We often hang out in large flocks.

European Starling
Sturnus vulgaris

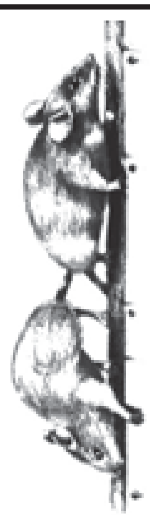
Rio Manso

House Sparrow
Passer domesticus

I am a small brown bird with a short, cone-shaped bill. My European relatives were brought to New York in the early 1850s and by 1940 were in the Rio Grande Valley. I have successfully colonized here because I strongly claim cavities for my nests very early in the year, before other birds arrive. I am common around houses and buildings but not very common in the bosque itself. I eat food on the ground, mostly insects, worms, garbage and seeds.

I am a small brown bird with a short, cone-shaped bill. I came from far away but have been very successful in the Rio Grande valley—just look how many of us there are! I build my nest in places very early in the year, before other birds arrive. I am common around houses and other buildings. I eat food on the ground, mostly insects, worms, garbage, and seeds.

House Mouse
Mus musculus



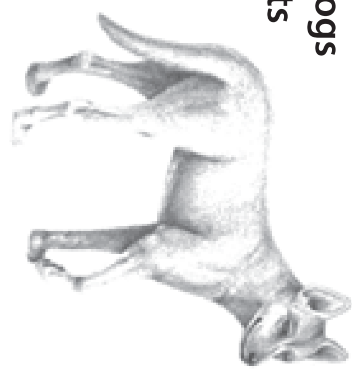
I have gray-brown fur, top and bottom. My scaly tail has little hair on it. My ancestors probably arrived in North America with the first colonists. I do well in areas near humans. I move inside buildings when it gets cold. I usually have four or five young in a litter and they, in turn, can have young six weeks later. I have several litters a year. I eat vegetable matter and bugs.

I have gray-brown fur, top and bottom. My scaly tail has little hair on it. I like to live near humans. I move inside buildings when it gets cold. I usually have four or five young in a litter. They can have young when they are only six weeks old. I eat vegetable stuff and bugs.

I should be a pet, but I am wild. Since I was abandoned by humans I try to survive on my own. I find lizards and mice to eat. I usually find the native mice are slow and easy to catch. Birds like ducks and quail that nest on the ground can also provide a good meal. I have become afraid of humans so I roam at night looking for food.

I should be a pet, but I am wild. Since humans left me here alone, I try to survive on my own. I find lizards and mice to eat. The native mice are slow and rather easy to catch. Birds that nest on the ground also provide a good meal. I am afraid of humans so I roam at night looking for food.

Feral Dogs and Cats



Who Lives Where? cards

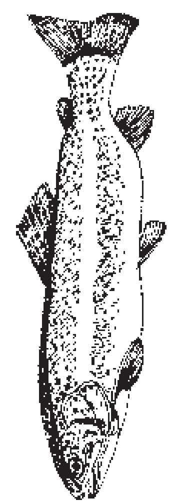
Part 2B: Rio Manso: Upper Watershed Adaptations: Introduced

Text for older students top in single-line box, for younger students below in larger type in double-line box.

The following cards are for use with the model set up as Rio Manso, the tamed river, for upper watershed sites (upper tributaries or areas north of the Middle Rio Grande). Use them if your school is located in the upper watershed or if you want to study the upper watershed.

I have a dark back, polished silvery sides, a red band along the lateral line, shimmers of green and blue in the sunlight and black specks from head to tail. I am almost every color of the rainbow! I have been transplanted from my home waters in the Pacific Northwest. I prefer clear, cold water with plenty of dissolved oxygen and many places to hide. In New Mexico I live in the tributaries of the Rio Grande as well as in several cold mountain lakes. I catch insects in the water or near the surface.

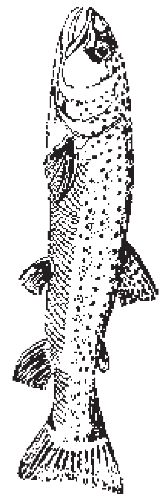
I have a dark back and a red band along my silvery sides. Green and blue colors show in the sunlight and I have black dots from head to tail. I am almost every color of the rainbow! I came here from my home waters in the Pacific Northwest. In New Mexico I live in cold, smaller streams that flow into the Rio Grande. I also live in some cold mountain lakes. I catch insects in the water or near the surface.



Rainbow Trout
Oncorhynchus mykiss

I have a sleek, colorful olive-brown body that sparkles with gold. My upper sides are dotted with black and sprinkled with blue-haloed red and orange spots, although my tail has no spots. I live in coldwater streams and lakes, but I prefer deeper, slower and warmer streams than other species like me. I eat minnows and aquatic insects. My species was introduced to North America in 1883. Now I am commonly found throughout the US, including some tributaries of the Rio Grande. I am wary and difficult to catch. I hide under a log or in a rock crevice when startled.

I have a sleek and colorful olive-brown body that sparkles with gold. My upper sides have lots of black, bluish-red and orange spots. I live in small to large coldwater streams and lakes. I eat minnows or water insects. My species was brought to North America in 1883. Now I live in some of the smaller streams of the Rio Grande watershed. I hide under a log or behind a rock when scared.



Brown Trout

Salmo trutta

Threatened and Endangered Animals

An **endangered species** is an animal or plant that may very soon go extinct. When extinct, every individual of that species is gone; not one is alive anywhere. That species is gone from the Earth forever. The term **"extirpated"** is used when a species no longer occurs in a given locality, such as the Middle Rio Grande Valley, but still survives in other places (also referred to as "locally extinct"). A **threatened** species is reduced in numbers and is on its way to becoming endangered and then going extinct. The purpose of listing a species as threatened or endangered is to protect and restore the species to a point where its populations are stable and no longer in need of special protection. The federal Endangered Species Act offers protection both directly for a listed species and for the ecosystems or habitats on which it depends.

The federal government, through the United States Fish and Wildlife Service, lists species as threatened, endangered or extinct. The state government, through the New Mexico Department of Game and Fish, makes its own list of state endangered, threatened or extinct species. The New Mexico Department of Game and Fish also designates Species of Greatest Conservation Need (SGCN) in the State Wildlife Action Plan for New Mexico (SWAP), which includes species that are declining, vulnerable, **endemic** (native and restricted to a certain place), **disjunct** (populations separated geographically) and/or **keystone** (a species that has a disproportionately large effect on its environment relative to its abundance). Natural Heritage New Mexico, a division of the Museum of Southwestern Biology at the University of New Mexico, also ranks plant and animal species, and plant communities, as to their endangerment status and monitors these species closely. Some species may appear on one list and not another, or they may be on all of the lists.

Over forty percent of fishes native to the Middle Rio Grande Valley are no longer here, with at least five species extirpated and two additional species considered extinct. Many factors have contributed to this loss, including pollution, reduced water flow, dams, increased erosion on land leading to more sediment in the water, and introduction of non-native fish species.

Some interesting fish had life cycles that included living part of their lives in the freshwater Rio Grande and part over 1,500 miles (2,400 km) away in the Gulf of Mexico. Such species have been negatively impacted by dams and diversion structures in the Rio Grande. For example, the **American eel**, *Anguilla rostrata,* spawns at sea, in the Sargasso Sea to be exact, after which young females travel up freshwater rivers and can live for 20 - 50 years. Most males stay in the ocean near the shore until females return to the spawning area where they mate, and it is assumed that both sexes then die. It takes three years for the young to get back to fresh water. Eels were historically present in the Rio Grande and the Pecos and maybe also the Canadian River. More recent sightings suggest that eels reintroduced in Colorado may have made their way into New Mexico rivers. Although still considered extirpated from the Rio Grande, eels also occur in the Mississippi River Valley, having been found as far upstream as North Dakota. Eels are not listed federally and populations are considered stable globally. The

freshwater drum, *Aplodinotus grunniens,* today lives primarily in the salt–freshwater mixed zone of the mouth of rivers. It still comes up the Rio Grande a short way, but cannot make it very far. Remains have been found in archeological sites near Cochiti and Albuquerque with evidence that drum made up a significant component of the fishery of the pre-alteration Middle Rio Grande. Also presumed extirpated from the Rio Grande in New Mexico, populations outside the state remain secure.

The following species are in the "Who Lives Where?" bosque animal activity and are, or have been in the past, threatened or endangered, or are now extinct.

Rio Grande Silvery Minnow, *Hybognathus amarus*

Federal: Endangered; State: Endangered, Species of Greatest Conservation Need

The silvery minnow was placed on the federal endangered species list in 1994. Today you can find this minnow in the Rio Grande only between Cochiti Dam and Elephant Butte Reservoir, a small portion of its historic range. It is endangered due to poor water quality, changes in the structure of the riverbed, lack of water in the river due to irrigation and drought and the presence of non-native species. The minnows lay eggs with the peak spring flows, and the young develop in quiet backwater areas after overbank flooding (See Chapter 2, Introduction, for more information). In 2000, a silvery minnow egg salvage pilot program was begun to increase the likelihood of survival. Managers have allowed high water releases from Cochiti Dam, mimicking the natural flood pulse, with a goal to promote natural breeding in years with high snowpack. As of fall of 2019, over 800,000 minnows hatched in captivity have been returned to the river, but the population is still at great risk.

Rio Grande Bluntnose Shiner, *Notropis simus simus*

Extirpated from New Mexico, may be extinct overall

Last collected in 1964 near Peña Blanca and previously listed as endangered in New Mexico prior to its extirpation. Extinction is suspected as a result of its habitat periodically drying up and the river channel being modified due to water diversions, dams and drought, and possibly competition with introduced species. The **Pecos bluntnose shiner** (*Notropis simus pecosensis*) is listed as threatened federally and as endangered and a Species of Greatest Conservation Need at the state-level.

Shovelnose Sturgeon, *Scaphirhynchus platorhynchus*

State: Extirpated (extinct in New Mexico)

Only one voucher specimen of this fish has been found in New Mexico (in 1875); however, archaeological evidence indicates the fish was eaten in earlier times. One theory to explain the early extinction of this species in New Mexico relates to the sturgeon's lifecycle. The larval fish drift far downstream, and the adults must return to their birthplace to reproduce. Dams interfere with the movement of these big river fish that require long distances to complete their lifecycle.

Northern Leopard Frog, *Lithobates pipiens*

State: Species of Greatest Conservation Need

All five species of leopard frogs in New Mexico are being carefully monitored and all are considered SGCN. The northern leopard frog was listed on the Navajo Endangered Species List as "threatened" in 1997 but has not been placed on state or federal lists. The **Chiricahua leopard frog** (*Lithobates chiricahuensis*) is considered threatened federally, while the **lowland leopard frog** (*Lithobates yavapaiensis*) is on the state endangered species list and may have been extirpated from New Mexico. Although scientists are not sure exactly why leopard frogs have declined dramatically, many suspect that competition with and predation by introduced bullfrogs or predation by introduced fish or crayfish may be major factors. Other reasons leopard frogs may be declining include damage to their habitat, pollution, pesticides, drought, climate change and disease from the chytrid fungus.

Greater Sandhill Crane, *Grus canadensis*

Although not currently listed as endangered or threatened, Greater Sandhill Cranes were rare in the 1930s with fewer than 1000 birds in the Central Flyway. This was primarily due to loss and degradation of wetland habitats. The Bosque del Apache National Wildlife Refuge was established in 1939 in part to provide wintering habitat for Greater Sandhill Cranes. Only 17 wintered there in 1941, but now populations have recovered enough that they appear to be secure in New Mexico. In contrast, the **Whooping Crane** (*Grus americana*) is listed as endangered at the federal and state level and is considered extirpated from New Mexico.

Bald Eagle, *Haliaeetus leucocephalus*

State: Threatened, Species of Greatest Conservation Need

Once widespread throughout the United States, a decline in the southern and eastern parts of the Bald Eagle's range in the 1900s led to its federal listing as endangered. A ban on DDT helped populations recover and, by mid-1995, it was down-listed to threatened. In 2007, it was delisted due to its successful recovery. Major threats remain, however, including habitat loss, nest and roost disturbance by humans, environmental contamination, decreased food supply and illegal shooting, so it is still considered threatened and a Species of Greatest Conservation Need by the state of New Mexico. It is also protected under the Migratory Bird Treaty Act and permits are required for many activities related to the Bald Eagle.

Yellow-billed Cuckoo, *Coccyzus americanus*

Federal: Threatened; State: Species of Greatest Conservation Need

Western populations of Yellow-billed Cuckoos, including those along the Rio Grande, are considered threatened at the federal level and a SGCN by the state of New Mexico. The local subspecies needs large patches of dense riparian forest with fairly dense understory to nest, preferring tall cottonwoods and willows, so it is particularly affected by loss and degradation of habitat. Given the need for dense vegetation, it can also be harmed by removal of exotic vegetation or death of the vegetation due to the introduced tamarisk leaf beetle if there are no native plants that can regrow in the treated area. The eastern population is considered a Species of Greatest Conservation Need in the state.

Southwestern Willow Flycatcher, *Empidonax traillii extimus*
Federal: Endangered; State: Endangered, Species of Greatest Conservation Need

The Southwestern Willow Flycatcher was listed as endangered at the federal level in 1995 and at the state level in 1996. It nests in dense willows and other woody plants that overhang rivers, streams, or wetland habitat. This habitat has been dramatically reduced in the last few decades. When the river was straightened, wetland areas were drained for agriculture. Wetlands were also reduced by the loss of spring flooding. Another contributing factor to the Southwestern Willow Flycatcher's decline is parasitism by Brown-headed Cowbirds. Cowbirds lay their eggs in the nests of other birds, leaving those parents to raise the cowbird chicks. Cowbird eggs hatch earlier than the eggs of the host species, like the Southwestern Willow Flycatcher, and cowbird nestlings are generally bigger and stronger. Cowbird chicks are more aggressive and out-compete chicks from other species for food. Although native, Brown-headed Cowbirds expanded their range with the clearing of forests and the introduction of cattle. They have had a dramatic effect on many species in the Southwest.

New Mexico Meadow Jumping Mouse, *Zapus luteus luteus*
Federal: Endangered; State: Endangered, Species of Greatest Conservation Need

The New Mexico meadow jumping mouse, *Zapus hudsonius luteus*, was listed as federally endangered in 2014. In 2017 this subspecies, which includes all New Mexico populations, was determined to be genetically and ecologically distinct enough to be considered a new species, *Zapus luteus luteus*. This mouse lives in streamside vegetation, wetlands and wet meadows. Its numbers declined when marshes and meadows were drained in the 1930s. Today, the areas where they are found are far from each other and are only small patches of habitat. They often now live along ditches or drains with willows and other vegetation. They are threatened by changes to habitat, due to grazing, drought, development, wildfire, and loss of beavers.

San Juan River Fish Species:

Two species of fish included in the San Juan River adaptation of the *Guide* are also considered endangered. The **Colorado pikeminnow** (also called Colorado squawfish, *Ptychocheilus lucius*) is listed as a federal and state endangered species, as well as a Species of Greatest Conservation Need. Threats to this species include predation from non-native fish, insufficient prey base, habitat loss or alteration, migration barriers and flow modification. The **razorback sucker** (*Xyrauchen texanus*) is also a federal endangered species and a Species of Greatest Conservation Need in the state of New Mexico. This species has been impacted by flow modification, habitat loss/alteration and the introduction of non-native fish.

INTRODUCED AND NON-NATIVE SPECIES

In the Middle Rio Grande Valley, there are many species that have only recently taken up residence. These plants and animals are taking over areas that native species have lived in for thousands of years. There are many reasons that non-native species may be successful, but, in general, they arrive here without the animals or plants adapted to eat or compete with them in their native environment.

Introduced Plants

There are three introduced trees that are very common in parts of the Middle Rio Grande Valley: **tamarisk/saltcedar** (*Tamarix chinensis*), **Russian olive** (*Elaeagnus angustifolia*), and **Siberian elm** (*Ulmus pumila*). In general, they are increasing because human-caused changes in the river valley provide favorable conditions for them to grow.

Saltcedar trees flower and produce seeds throughout the growing season; their reproduction is not restricted to spring/early summer as is the reproduction of native cottonwoods. When bare ground is colonized late in summer by saltcedar, it will not be bare in the spring when cottonwoods are sending out seeds. Both Russian olive and Siberian elm can sprout in shaded areas, under the canopy of the cottonwoods, and are becoming very common in the bosque.

Fires in the bosque are much more common today than in previous centuries. Human-caused fires from factors such as fireworks destroy many acres of the bosque each year. Cottonwoods can survive low- to moderate-severity fires and can re-sprout after high-severity fires, but survival of the aboveground tree tends to be low after high-severity fires. Although the sprouts can grow quickly, it takes some time before they are able to produce seed. Both saltcedar and Russian olive can re-sprout after fires, while aboveground parts of the plants tend to be killed. These species often reestablish after fires more quickly than cottonwoods with seeds coming from plants either close to or upstream from the burned site. Their ability to produce seeds for a longer period than do cottonwoods makes it even more likely that they will reestablish following a summer fire. Also, saltcedar that survive a fire can increase flowering and seed production, again giving this species an advantage in reestablishment over cottonwoods.

Cavity-nesting birds (such as nuthatches, chickadees, and woodpeckers) are an important part of the bosque ecosystem. They use the large cottonwoods to build their nests, but they have not been seen nesting in saltcedar or Russian olive. These introduced trees do not provide suitable cavities for nests. If the number of native trees in the Rio Grande bosque continues to decline while introduced tree species increase, we may see a change in some of the wildlife along our river corridor.

However, attitudes toward these introduced plant species have shifted somewhat among resources managers. Although the goal was once to eliminate non-native plants, it is now understood that a return to conditions in pre-exotic ecosystems is impossible. In many areas, keeping some non-native plants may be necessary to provide habitat for native animals. For example, saltcedar can alter the soil and prevent native plants from growing, even after the saltcedar is removed. In such cases, it is better for birds and other wildlife to have saltcedar than a field of weedy, herbaceous plants, and many native animals will use the saltcedar habitats. There are still efforts to control these introduced plants, but also an acceptance that they will remain part of the riparian ecosystem into the future.

Introduced Fauna

Arthropods

The **isopods**, commonly called pillbugs (*Armadillidium vulgare*) and woodlice (*Porcellio laevis*), were brought to this continent in the holds of ships. Ships carried dirt as ballast on their trips to North America but then dumped the soil to load cargo bound for Europe. Isopods spread from these deposits. In the Rio Grande Valley, the isopod has become the major **detritivore** (eater of dead plant material). **Field crickets** *(Gryllus* sp.*)* filled this role before, but are now reduced in numbers. Crickets do well in areas that receive spring flooding, but isopods tend to be more numerous in drier sites.

A Tale of Two Exotics

The extensive spread of **tamarisk** (saltcedar) has led resource managers to try a variety of techniques to control this invader, including herbicides and mechanical removal, which have proven difficult and labor intensive. Although it is highly flammable, tamarisk also recovers quickly after fire. Where the plant grows aggressively, it dramatically alters the local habitat, impacting native plants and animals. In the mid-1980s, a search for a biological control agent began. Ultimately, four species of Old World *Diorhabda* beetles were selected to fill this role. The U.S. Department of Agriculture (USDA) launched the **tamarisk beetle program** in 2001, with beetles released at ten different sites in the western US. The beetles are specific to tamarisk trees, so they do not threaten native plants. The larvae can rapidly defoliate a tree, though they don't tend to kill the plants initially. Still, with multiple generations of beetles produced in one growing season, they can greatly reduce tamarisk cover, up to 50-90% in some places. The goal is not to completely eliminate tamarisk, but to reduce its impact enough that native plants can recover. Reduction in live tamarisk has been successful. However, in some places, it may be too successful. Some populations of Southwestern Willow Flycatcher, including some in New Mexico, nest in tamarisk thickets, particularly where native vegetation has been completely displaced. With concern for the flycatcher as the impact of tamarisk beetles spread, the USDA ended the program in 2010. The beetles were not expected to move south, where it was thought that warmer weather would limit their survival. The beetles have expanded their range, however, including into the Middle Rio Grande Valley by 2012 where they, and their host plants, are likely to remain a part of western riparian ecosystems into the future.

Fish

The installation of Cochiti Dam has changed the temperature and the amount of water released downstream throughout the year. These modified conditions change the species of fish able to survive in the reach below the dam and, in some cases, favor non-natives. Non-native fishes have been introduced to the Middle Rio Grande both accidentally and by intentional New Mexico Department of Game and Fish stocking programs. There has been a corresponding reduction in the numbers and distribution of native fishes as the new species compete for food or prey directly on native species. One such species is the **brown trout** (*Salmo trutta*), which is native to Europe. Brown trout now reproduce naturally in many of New Mexico's streams and rivers, and these non-native fish prey upon our native trout, including the **Rio Grande cutthroat** (*Oncorhynchus clarki virginalis*). In some cases, an introduced relative is hybridizing with the native species. For example, the native **Pecos pupfish** (*Cyprinodon pecosensis*) is listed as threatened and a Species of Greatest Conservation Need by the state. The biggest threat to this species is hybridization with the non-native **sheepshead minnow** (*Cyprinodon variegatus*). While the **western mosquitofish** (*Gambusia affinis*) is native in some parts of the Rio Grande and other streams in New Mexico, mosquitofish have been introduced to control mosquitoes in the Middle Rio Grande Valley, as some eat mosquito larvae. This competitive and aggressive species is actually distributed by the City of Albuquerque for mosquito control. Never release mosquitofish, or any other pet fish, into the wild as they threaten our native aquatic ecosystems!

Amphibians

Although native to the eastern U.S., it is unknown whether **bullfrogs** (*Rana catesbeiana*) are native to New Mexico. They were introduced throughout the west, probably including part of New Mexico, to provide a source of frog legs for people to eat, and this is likely how they got into the Middle Rio Grande. Bullfrogs are large frogs that eat almost anything they can capture and swallow, even ducklings! They are known for eating other frogs and have been blamed for the decline of several species. The Northern leopard frog may have declined in part due to predation by bullfrogs.

Reptiles

Native to the Pecos and Canadian river drainages, the **red-eared slider** (*Trachemys scripta*) has been introduced to the Rio Grande. This is the common, aquatic pet turtle species, that has been released by short-sighted pet owners. The red-eared slider can hybridize with the **Big Bend slider** (*Trachemys gaigeae*), that is native to the Rio Grande and considered a Species of Greatest Conservation Need in New Mexico. Big Bend sliders have a very limited range in New Mexico, occurring only from Bosque del Apache National Wildlife Refuge south to Caballo Lake, although they also occur in Texas and Mexico. Hybridization threatens the persistence of this species. Never release pet turtles into the wild!

Birds

European Starlings (*Sturnus vulgaris*) were introduced into Central Park, New York City in 1890; by 1952 they were found across the United States. They primarily eat insects but also eat seeds and scavenge garbage. They nest in cavities and so compete directly with native, cavity-nesting birds. Starlings nest early in the year and are very aggressive about claiming nest holes. They may even evict the large woodpeckers that excavated the hole! Many species of birds are now reduced in numbers due in part to competition from starlings.

House Sparrows (*Passer domesticus*) were introduced to Brooklyn, New York, in the early 1850s and subsequently to various cities across the United States. They had spread throughout the country by the early 1900s. They live in and around buildings, close to humans. Like starlings, House Sparrows start nesting earlier in the year than native birds and claim prime nesting habitat (they nest in cavities but can also build a bulky nest in dense vegetation). They may even appropriate nests of other birds, killing eggs and nestlings if occupied. House Sparrows tend to have several broods a year.

Rock Pigeons (*Columba livia*), also known as Rock Doves, are common and widespread, particularly around towns and cities, though they also make use of riparian woodlands. They compete with native species for habitat and forage. The **Eurasian Collared-Dove** (*Streptopelia decaocto*) is a more recent immigrant but is increasing in abundance and spreading. Like the pigeon, it may negatively affect native species as it competes for habitat and forage.

Mammals

House mice (*Mus musculus*) move along with humans into an area. They have large numbers of young that can reproduce when only two months old. Although they are not common in bosque sites away from the city, in the Albuquerque bosque they are often captured in areas of dense vegetation, especially near water. They do not tend to be in areas of mature cottonwoods. With more human development in or near the bosque, and a shift in vegetation, house mice will likely spread into more areas. The **Norway rat** (*Rattus norvegicus*) was also introduced to the valley and is found in agricultural areas, but is not very common in the bosque. Although these non-native rodents can cause problems, note that when poisoning rodents the poison can be passed up the food chain and will affect other, possibly native bosque species. Don’t poison our native animals!

Feral cats (*Felis catus*), and pet cats allowed to wander outdoors, eat native rodents, birds, lizards and amphibians. Studies estimate that free-ranging domestic cats in the US kill 1.3 – 4.0 billion birds and 6.3 – 22.3 billion small mammals every year! Keep your cats indoors to protect wildlife!

Feral dogs (*Canis lupus familiaris*) often roam in packs and also eat many native animal species. They can easily kill ground-nesting birds such as ducks and geese or destroy their nests and eggs. Feral dogs can also threaten people and their pets. Never release puppies or dogs into the wild!

SUMMARY

Introduced and non-native species have had, and continue to have, a great impact on the native plants and animals of the Middle Rio Grande bosque. Many of these introductions happened years ago. The people releasing the animals or bringing in the plants did not know the effects they would have. It is with hindsight that we wish some of these species had not been brought here. Today, we should not repeat the mistakes of the past. Do not release unwanted pets into the bosque or any river, drain, or ditch. An unwanted kitten or puppy should be taken to Animal Control or the Humane Society. Don’t vacation in another state or go to a local pet store and bring home an animal, such as a turtle, for a pet, then let it go in the bosque when you can’t take care of it any more. There are also strict rules about collecting wild animals or moving them between states; you don’t want to break the law! We have a rich and diverse population of plants and animals particularly adapted to the Middle Rio Grande Valley. We should work hard at learning about the natural ecosystem and keeping our native species abundant and healthy.

16. Who Grows Where?

Bosque Plants

Description: Students explore plants and the role plants play in the bosque ecosystem using the Changing River model and see how human-caused changes to the bosque impact the ability of plants to survive and thrive over time.

Objectives: Students will:

- explain structure and function/adaptations of plants surviving in the bosque;
- compare conditions for survival of plants in the past, present and optimal future of the bosque;
- analyze the impacts of human-caused changes to the bosque on native plants; and
- describe the effects of introduced/exotic plants on native plants.

Materials:

- Scissors to cut the pieces
- Envelopes or plastic sandwich bags to hold the pieces and information cards
- Who Grows Where? plant pictures and description cards
- "Changing River" activity materials for Rio Bravo, Rio Manso and Rio Nuevo

16. Who Grows Where?

Grades: 7–12 [appropriate for some 3-5]

Time: Material preparation: 15–20 minutes. Activity: one 40-minute class period

Subjects: science

Terms: *alkaline, alkaloids, awn, basal, catkins, floret, genus, germinate, panicle, petals, phreatophyte, pollinate, rhizome, riparian, sepals, species, spikelet, spores, stamens, stomates/stomata*

Some common words with special plant meanings: *alternate, annual, compound, diameter, opposite, perennial, simple, teeth* (on leaf edges), *trunk*

New Mexico STEM Ready! / Next Generation Science Standards

NGSS DCIs and New Mexico State Performance Expectations

3.LS2.C Ecosystem Dynamics, Functioning & Resilience
3.LS4.C Adaptation
3.LS4.D Biodiversity & Humans
4.LS1.A Structure & Function
5.LS2.A Interdependent Relationships in Ecosystems*
5.ESS3.C Human Impacts on Earth Systems
MS.LS1.B Growth, and Development of Organisms
MS.LS2.A Interdependent Relationships in Ecosystems
MS.LS2.C Ecosystem Dynamics, Functioning & Resilience
MS.LS4.D Biodiversity & Humans
MS.ESS3.C (MS-ESS3-3 NM) Human Impacts on Earth Systems

NGSS CCCs

Patterns; Cause and Effect: Mechanism & Explanation; Systems & System Models*; Energy & Matter: Flows, Cycles & Conservation; Structure & Function; Stability & Change

NGSS SEPs

Asking Questions & Defining Problems; Developing & Using Models; Constructing Explanations & Designing Solutions; Engaging in Argument from Evidence; Obtaining, Evaluating & Communicating Information*

(* indicates extension activity)

Procedure:

- Prior to the activity, cut out the plant pictures and information cards for each plant. (There is only one description card for each plant, targeted for upper elementary and middle school students.) We recommend copying the Rio Bravo plants and descriptions on a different color paper than the Rio Manso plants. Keep the original as your key to match the sets; you may want to code the pictures and descriptions. (A list is included below.) It is best if the name of the plant appears only on the picture and not the description.

- Revisit the KWL charts, to consider what students already **Know** about the plants that live along the river and floodplain (see Appendix K).

  Ask students:

  What plants live along the river or in the bosque?
  How are these plants especially suited to live in this environment?
  What about the structure of a plant or its particular features allows it to survive there?

  (Asking Questions & Defining Problems)

- Vocabulary: A list of common terms is provided (see “Common Botanical Terms” in the activity “A Rose by Any Other Name” in Chapter 3). You might want to familiarize the students with the vocabulary, go over the parts of a plant and introduce some botanical terms. Or, you may prefer to wait and give opportunities to learn vocabulary as needed during the activity.

Section A: Rio Bravo

- Prior to the activity, set up the river as Rio Bravo (see activity 13, "Changing River").

Then follow Option A or Option B, below:

Option A

Plant Match: Pull one pair of cards for every pair of students in the class. (20 students = 10 plants with both illustration and description cards for each plant) Each student gets either a picture or a description of one Rio Bravo plant. Give students with descriptions a few moments to read about their plants. Taking turns, have each student summarize the description of their plant. Challenge the students to find their "partner." Class members should guess which plant is being described. The student who has the corresponding drawing should place the plant on the model in the habitat that was described. Continue around the room until all of the plants are described and plant drawings are placed on the model.

Option B

If you have less class time, hand out the plants with their matching descriptions cards to the students. Each student should have at least one plant of his or her own. Have the student carefully read the description and decide where that plant grows. *What is its habitat?* Students should then place the plant on the bosque model in a location where it would grow best. (Place them on the Rio Bravo bosque before placing the ditches, levees and homes). *Have each student describe his or her plant and where it grows to the entire group.* Do another round with other plant cards, if appropriate.

Rio Bravo Discussion Questions:

Think about how plants grow, get nutrients and water, survive herbivores or competitors, reproduce and endure seasonal changes.

What helps each plant survive? What features/structures does each plant have that allow it to live along the river or in the bosque?

(3.LS4.C; 4.LS1.A; MS.LS1.B; MS.LS2.A; Cause & Effect; Structure & Function)

Look for patterns of where plants are found along the river and floodplain.

Look for features that plants have that allow them to survive in their habitat and that might be shared by different species (i.e., something that helps them survive spring flood waters, etc.?)
(Patterns)

Plants provide perfect examples of how shape and function help an organism to survive.

How are different species similar or different in the way they are shaped and how they function?

Are any particular plant structures more suited to life along the river or in the bosque compared with drier habitats?
(Structure & Function)

Think about annual and seasonal changes to the river through the spring runoff and the associated flood pulse.

Which plants need high spring water flow?

Which plants will "move" into newly changed/disturbed areas? Make an argument for how plants might move! Discuss in small groups.

Which plants will no longer grow in the flooded areas, or in areas that have been flooded? **(3.LS2.C; MS.LS2.A; MS.LS2.C; Stability & Change; Constructing Explanations & Designing Solutions; Engaging in Argument from Evidence)**

- Do activity 18, "Bosque Chaos," on the model.

  How do the "Bosque Chaos" changes affect the plant species that live there?

  List ways species continue to thrive in these changing conditions throughout the year. **(3.LS2.C)**

Section B: Rio Manso

- Add the human alterations to the bosque model: irrigation ditches, levees, jetty jacks, etc. (Rio Manso).
- Place the introduced species on the model, using the method from Option A or Option B above.
- Have students describe any changes to the habitat and how they think these changes will affect the plant they originally placed on Rio Bravo.

  Which plants are thriving because of the changes and which have lost habitat? **(3.LS2.C)**
- Have the class review the "Introduced and Non-native Species, Introduced Plants" section in the "Who Lives Where?" activity.

Rio Manso Discussion Questions:

Think about how human-caused changes affect the availability of resources. For example, alterations to the river channel and amount of water (overbank flooding, groundwater) have affected bosque habitats.

Make a chart showing which plants are surviving well, which no longer grow in this area, which "move" in, and which may be endangered following these human-caused changes. **(3.LS2.C; MS.LS2.C; Patterns; Cause & Effect; Structure & Function; Stability & Change)**

Think about introduced/exotic species. For example, cottonwoods produce seeds during a short period of time coinciding with the spring flood pulse, while saltcedars produce seeds throughout the summer.

Do some of the non-native plants affect how well species of native plants survive in the bosque? If so, how?

What adaptations do these introduced plants have to allow them to thrive and out-compete some native plant species? For example, compare saltcedar and cottonwood.

What happens if some of these native species are no longer here in the future? **(3.LS4.C; 5.LS2.A; MS.LS2.A)**

Do human activities affect native plants? If so, how?
What can our local community do to help protect native species?
(3.LS4.D; MS.LS4.D)

Look at the KWL charts the students created at the beginning.
*What have they **Learned?** What additional questions do they have now?*

Section C: Rio Nuevo

- Post this question for your class KWL charts.

  Given that we have introduced species (saltcedar, cheatgrass, etc.), what choices can we make to minimize their effect and to maximize the success of native species?

  First individually think of ideas, then discuss in pairs or small groups, then share with the full class.

- *What ideas do students have that will make habitats more suitable for native plants?*

  (Rio Nuevo Habitat Restoration Project Cards from "Changing River" can be used to stimulate discussion.) Adjust the model pieces to reflect suggested changes (e.g., add in sandbars, add wetlands, remove exotic species, etc.).

  Develop a justification for the move.
  How do these restoration projects change the available habitat? Are there any potential negative consequences to these suggested changes?
  Are native plants helped by these changes? How so or why not?
  Which plants are helped, and in what way are they helped?
  (5.ESS3.C; MS.ESS3.C; Cause & Effect: Mechanism & Explanation; Constructing Explanations & Designing Solutions; Engaging in Argument from Evidence)

Assessments:

- Revisit the KWL charts. *What have they **Learned**? What else do students **Want** to know?* **(Asking Questions & Defining Problems)**
- Work in small groups. Model this bosque ecosystem as you understand it. Now take your model, and choose a plant to reduce (endangered) or add (non-native) to your bosque ecosystem. Based on changing that one component, model what happens to other parts of the ecosystem. Make a list of restoration projects that would help native biodiversity in your ecosystem. Make a poster showing your resulting ideas. Have the class do a gallery walk of posters; each team should explain their main ideas to the class.
  (Cause & Effect: Mechanism & Explanation; Systems & System Models; Asking Questions & Defining Problems; Developing & Using Models; Constructing Explanations & Designing Solutions)

Extensions:

- Plants provide an excellent path to understanding both matter and energy in ecosystems. *How do plants get the energy and matter they need? How might energy or matter be transported into, out of or within an ecosystem (consider the activity of animals, decomposers, flooding, etc.)?* Use the animal cards from "Who Lives Where?" with these plant cards to do "The Web" activity in Chapter 5 of this *Guide*; or to further understand the cycle of matter and flow of energy use the "Who Grows Where?" and "Who Lives Where?" cards in the "Energy in Bosque Ecosystems" activity in this *Guide*. **(5.LS2.A; Energy & Matter; Systems & Systems Models; Developing & Using Models)**
- Oral history extension: send plant drawings home with students to ask elders about local names, uses of the plants, and stories about them. Have students report their findings back to class. **(Obtaining, Evaluating & Communicating Information)**

Who Grows Where? Rio Bravo

Common Name	Scientific Name
Rio Grande cottonwood	*Populus deltoides* subsp. *wislizeni*
New Mexico olive	*Forestiera pubescens*
Coyote willow	*Salix exigua*
One-seeded juniper	*Juniperus monosperma*
False indigo	*Amorpha fruticosa*
Western white clematis	*Clematis ligusticifolia*
Screwbean mesquite	*Prosopis pubescens*
Wolfberry	*Lycium pallidum*
Prickly pear	*Opuntia* spp.
Giant sacaton	*Sporobolus wrightii*
Sedge	*Carex* spp.
Saltgrass	*Distichlis spicata*
Smooth scouring rush or horsetails	*Equisetum laevigatum*
Yerba mansa	*Anemopsis californica*
Hooker's evening primrose	*Oenothera hookeri*
Broad-leaved cattail	*Typha latifolia*
Sacred datura	*Datura wrightii*
Sunflower	*Helianthus annuus*
Spectacle pod	*Dimorphocarpa wislizeni*
Who Grows Where? Rio Manso	
Saltcedar	*Tamarix chinensis*
Tree of heaven	*Ailanthus altissima*
White sweet clover	*Melilotus alba*
Russian olive	*Elaeagnus angustifolia*
Cheatgrass	*Bromus tectorum*
Kochia	*Kochia scoparia*

NGSS CONNECTIONS TO WHO GROWS WHERE? - DISCIPLINARY CORE IDEAS

[Middle School details in Appendix K]

3.LS2.C Ecosystem Dynamics, Functioning & Resilience *When the environment changes in ways that affect a place's physical characteristics, temperature, or availability of resources, some organisms survive and reproduce, others move to new locations, yet others move into the transformed environment, and some die.*

Rio Bravo: The river and bosque experienced annual and seasonal changes through the spring runoff and associated flood pulse.
Which plants need high spring water flow? Which plants will move into newly changed areas?
Which plants cannot survive where they were before the spring flood?

Do the "Bosque Chaos" activity on the model.
How do the changes affect the plant species that live there?
List ways species continue to thrive in these changing conditions throughout the year.

Rio Manso: Human-caused changes to the physical characteristics of the river and bosque, such as changes to the water table and channel shape, influence the availability of resources for plants, which in turn affects plant survival.
Which plants are thriving because of the changes and which have lost habitat?
Make a chart showing which plants are surviving well, which move in, and which can no longer live here following these human-caused changes.

3.LS4.C Adaptation *For any particular environment, some kinds of organisms survive well, some survive less well, and some cannot survive at all.*

The riparian ecosystem supports many more plants than the adjacent arid uplands, yet certain species are present only in one habitat or the other. Different plants are adapted to different environments.
What helps each plant survive in the bosque?

Think about introduced/exotic species. *Do any introduced plants affect how well other species of plants survive in the bosque? If so, which species. What effect do they have?*
What adaptations do these introduced plants have to allow them to thrive and outcompete some native plant species?

3.LS4.D Biodiversity and Humans *Populations live in a variety of habitats, and change in those habitats affects the organisms living there.*

Although floodplain ecosystems are very dynamic, with frequent changes to habitats occurring at a local scale, native organisms are less able to deal with the types of changes caused by humans. Prior to human changes, the diversity of species in New Mexican riparian habitats was very high. Changes in floodplain habitats have affected the types of plants living there.
What types of changes in floodplain habitats have affected the plants that live there?
How do these changes in floodplain habitats affect which plants are present in the floodplain?

4. LS1.A Structure and Function *Plants and animals have both internal and external structures that serve various functions in growth, survival, behavior, and reproduction.*

Plants have a variety of structures that allow them to survive in given habitats. Think about plants in the bosque and along the river, and what structures help them to survive. Consider growing, getting nutrients and water, surviving herbivores or competitors, reproducing and enduring seasonal changes. During photosynthesis, plants open small structures called stomates to allow for gas exchange. Every time stomates open, they allow oxygen out and carbon dioxide in and at the same time, water vapor escapes the plant. There is a delicate balance for the plant to maximize photosynthesis while trying not to wilt from water loss. Plants have a variety of structures to reduce water loss.
What structures help each plant grow, survive and reproduce in the bosque or along the river?

5.LS2.A Interdependent Relationships in Ecosystems

The food of almost any kind of animal can be traced back to plants. Organisms are related in food webs in which some animals eat plants for food and other animals eat the animals that eat plants. Some organisms, such as fungi and bacteria, break down dead organisms (both plants or plant parts and animals) and therefore operate as "decomposers." Decomposition eventually restores (recycles) some materials back to the soil. Organisms can survive only in environments in which their particular needs are met. A healthy ecosystem is one in which multiple species of different types are each able to meet their needs in a relatively stable web of life. Newly introduced species can damage the balance of an ecosystem.

Think about this standard from the species perspective, and how the different species interact.
What does each plant need to survive? What consumes each plant?
How are the needs of each plant species met in a bosque ecosystem?
How are species affected by other species that are present?

Note that a decomposer card is in the "Energy in a Bosque Ecosystem" activity.
What is the role of decomposers in the food web?

Do the Rio Manso model and place the introduced/exotic species.
What effects do these new species have on native species?
What happens if some of these native species are no longer here in the future?

5.ESS3.C Human Impacts on Earth Systems *Human activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, ocean, air and even outer space. But individuals and communities are doing things to help protect Earth's resources and environments.*

Human activities have altered many habitats along the Rio Grande and its floodplain. Consider how the hydrological changes have affected habitats and how those changes affect the plants that live there.
What effects do human activities have on native plants?
What can our local community do to help protect native plant species?

Look at the Rio Nuevo model changes.
Which changes may help native plant species?
Which plants are helped, and in what way are they helped with Rio Nuevo changes?

Who Grows Where?

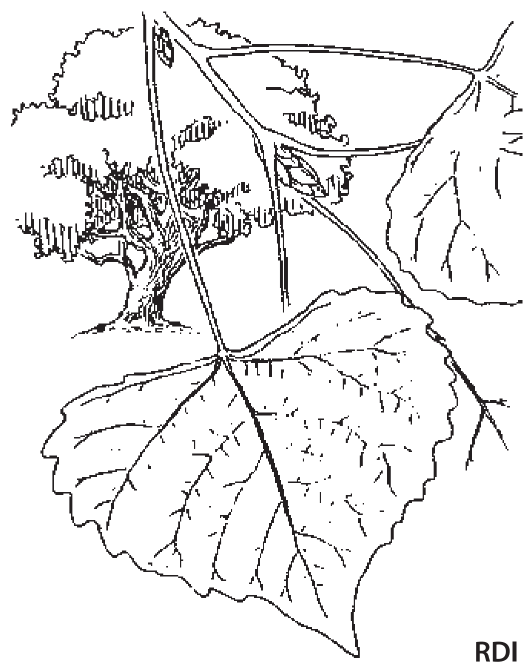
Drawings by Robert DeWitt Ivey (RDI) and George Mauro (GM)

Part 1: Rio Bravo

A majestic landmark species of the bosque, my trunk can reach 5 feet (1.5 meters) in diameter. My heart-shaped leaves have toothed edges. In autumn they turn yellow making the bosque appear as a river of gold. You can tell my sex in the spring. Male trees have red flowers that form conspicuous long clusters, or catkins, that produce pollen. The female flowers are hard to spot until they develop grape-like clusters of seed pods, or tetones (te-TOE-nes). Having evolved along the Rio Grande, I take advantage of high spring water runoff. In the late spring my seed capsules pop open and billions of minute cottony down-covered seeds are carried into the sky by wind. To grow they must land on moist, bare soil where they can receive a full day's sunlight. Once my seeds sprout, their roots must keep in contact with the moist soil as the water recedes and the water table drops.

Rio Grande Cottonwood

Populus deltoides subsp. *wislizeni*



RDI

I grow as an erect spreading shrub that can reach 10 feet or 3 meters tall. I have a smooth, whitish-green bark that makes me distinctive even in the winter when I have no leaves. My bright green oval-shaped leaves are arranged oppositely on my twigs. My species has separate male and female plants. My flowers bloom in the spring before my leaves emerge. Although my small flowers have no petals, the stamens give the flowers a yellowish cast. Females of my species make small blue-black olive-shaped fruits that are attractive to birds. I am native to the bosque and like both dry and moist soils. My roots can grow over 10 feet or 3 meters deep. My hard wood has been used by Native Americans for making digging and prayer sticks.

New Mexico Olive

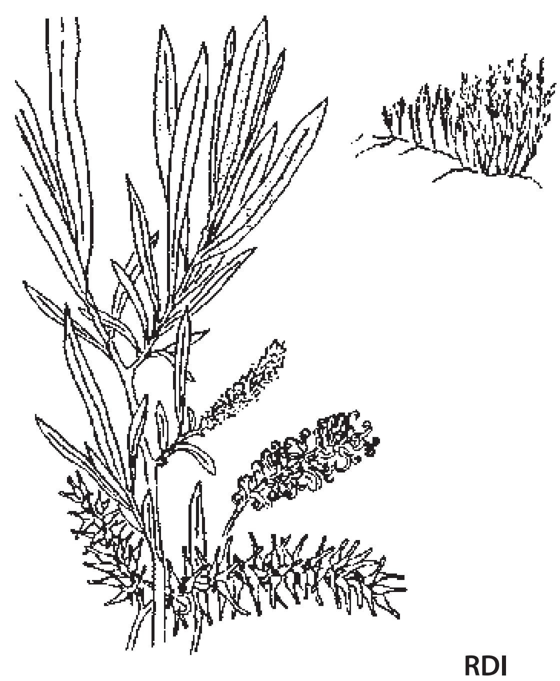
Forestiera pubescens

RDI

Flood waters don't bother me because my limber branches can ride in the water without my roots being torn from the soil. I like to grow in thickets along the edge of the river or streams. I am one of the most common riparian shrubs in New Mexico. I can grow into a 15-foot (5-meter) tall tree, but mostly I appear as a small shrub. My male flowers grow in tight, dense clusters called catkins. My female catkins have loosely arranged flowers that produce seeds with hairy filaments that are easily distributed by the wind. My long, lance-shaped, minutely toothed leaves are silvery early in the summer because of fine hairs. As the hair wears off I look more dull grayish green. Wildlife such as elk and beaver like to eat my branches. Like other members of the Salicaceae family, I have bark from which tea can be brewed and used to relieve pain.

Coyote Willow

Salix exigua

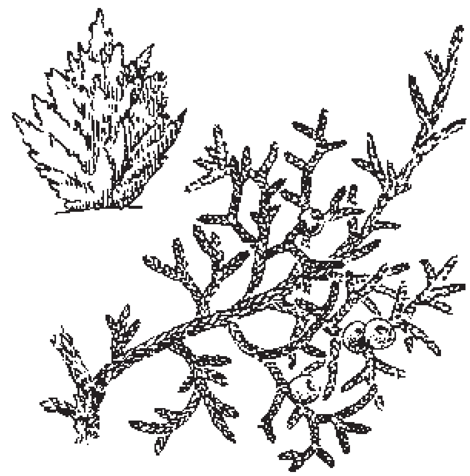


RDI

I am one of the most common small trees in New Mexico. I like to live in dry rocky plains, hills and mountains where I often grow with pinyon pine. I look brushy since my many branches grow from an underground trunk. Tiny scale-like leaves cover my twigs. My sometimes frosty-looking fruit appears to be dark blue to copper berries, but they are really cones. Birds and mammals, especially bear, like to eat my cones. My leaves, twigs, "berries" and bark smell wonderfully pungent. Navajos have used my bark for clothes, blankets and shoes. I do not grow in areas that flood or have high water tables, so the foothills, not the bosque, are my more common home.

One-seed Juniper

Juniperus monosperma

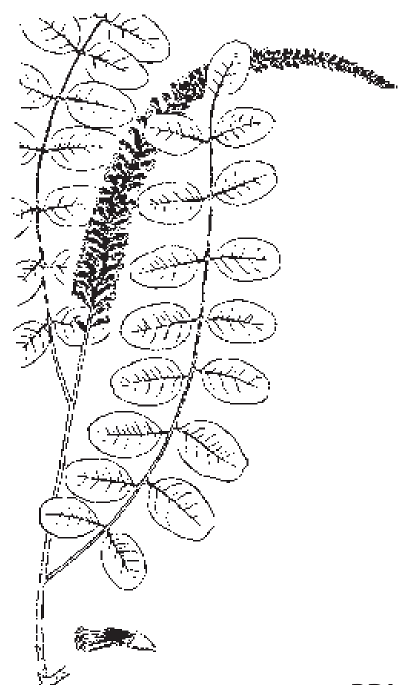


RDI

Look closely: my deep blue-violet flowers, from which I get my name, have only one petal. Stamens covered with bright yellow pollen extend beyond the petal. My flowers are grouped together in long, dense clusters at the end of my branches. I am a woody plant that usually grows about 6 feet (2 meters) tall. A member of the pea family, I have compound leaves with many opposite oval leaflets that are sometimes mistaken for locust leaves (I am not a locust!). I have a close relationship with bacteria that live in my roots. Together we add nitrogen, a vital nutrient, to the soil. I grow in moist, sandy soil near places where water is close to the surface. My many branches make nice places for bird nests.

False Indigo

Amorpha fruticosa



RDI

I am a vine that likes dry conditions. Also called old-man's beard, I have stems that grow along the ground or up into trees. My seeds form cotton-like masses of hairy fruits. I have no petals, but the sepals of my flower are creamy or purplish-brown in color and therefore look like petals. My leaves are opposite each other on a long slender vine and have three lobes, each with teeth or lobes of their own. As a perennial, I can be found in the same place year after year. I am a member of the buttercup family.

Western White Clematis

Clematis ligusticifolia

RDI

I am a spiny shrub or small tree with slender branches. My fruit look like screws. Each bean is coiled in a spiral with the same diameter. My compound leaves have four to eight pairs of small oval leaflets. My flowers are yellow to yellow-green or pale green in color with anthers ending in red glands. My fruit is sweet to taste and is eaten by humans, coyotes, and roadrunners. I have spines or thorns along my stems. My thorns are sometimes used by a bird called a loggerhead shrike as a place to store grasshoppers or lizards it plans to eat later. I grow well in the desert washes and dry streams that sometimes flow into the Rio Grande.

Screwbean mesquite

Prosopis pubescens

RDI

Red berries hang from my thorny stems during the summer and attract birds. I look like a mound of woody stems, with small narrow leaves in clusters on short spiky branches. In the winter I provide a little greenery. My early flowers are green lavender and shaped like tiny funnels and attract insects. Besides the berries, birds use me for cover and protected roosts at night. Native Americans used me for food: my slightly bitter, juicy berries were eaten raw or prepared as a sauce.

Wolfberry

Lycium pallidum

RDI

A common member of the cactus family, I like the sandy soils of the bosque. When undisturbed, I can grow into huge clumps. My stems are flattened pods, and what would be leaves on other plants are sharp prickly spines that grow in a pattern. My fruits are large and red to purple, juicy, and pear-shaped, containing many seeds. Wildlife and many people eat them. Animals like rodents and rabbits may eat my pads for their water needs. It is evident when coyotes eat me: their poop is the same red color and full of my seeds. That is how I spread from place to place. In the bosque I may have bright yellow flowers that all kinds of pollinators visit.

Prickly pear

Opuntia spp.

RDI

A native grass, I am adapted to living in dry soil but I also can be found near stream banks. I am a perennial and grow well in hard-packed alkaline soils. My panicle or seedheads are 8 - 24 inches (20 - 60 centimeters) long and the branchlets are densely flowered, producing many seeds for birds and small mammals. I grow in thick clumps and can reach heights of 6 feet (2 meters). My leaves are long, sword-shaped and tender to eat when young. As I grow older leaves are tough and less tasty. I provide cover for ground nesting birds and lizards.

Giant Sacaton

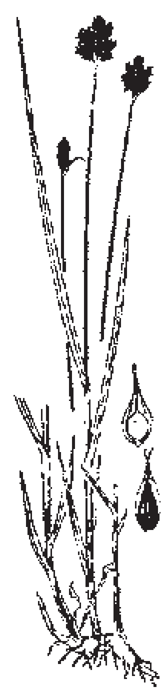
Sporobolus wrighti

RDI

I am a grass-like aquatic plant that grows along the banks of rivers and in marshes or shallow ponds. My stiffly edged stem is triangle shaped and has three long grass-like leaves. They sheath or wrap around the stem. I have seed clusters or nutlets that grow close to the stem. Ducks, Canada geese and muskrats will uproot me to eat. Dragonfly and mayfly nymphs crawl from the water up my stem and emerge in their adult form. Native leopard frogs hide from bullfrogs where I grow thickly. Many people use my name in the rhyme "_____ have edges" to remember my triangular stem.

Sedge

Carex spp.

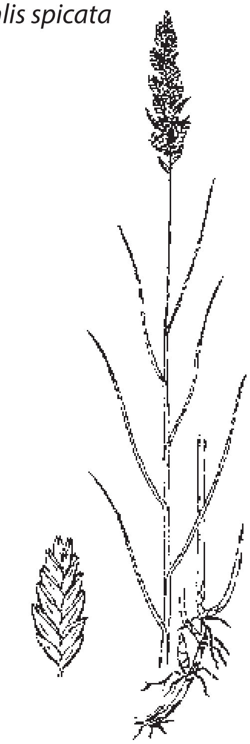


RDI

A native grass, I grow well in sandy alkaline (salty) soil of floodplains, swales or salt flats. I am a perennial and spread by vigorously growing underground stems called rhizomes (RYE-zomes). My long and slender leaves are opposite and sheath or wrap around the stem. The seed head appears condensed with many branches (spikelets) of tightly arranged flowers (florets) that each produce a seed or grain. Small mammals eat these seeds. I grow in clumps and prevent soil from eroding. I produce much plant material that decays and becomes part of the soil.

Saltgrass

Distichlis spicata

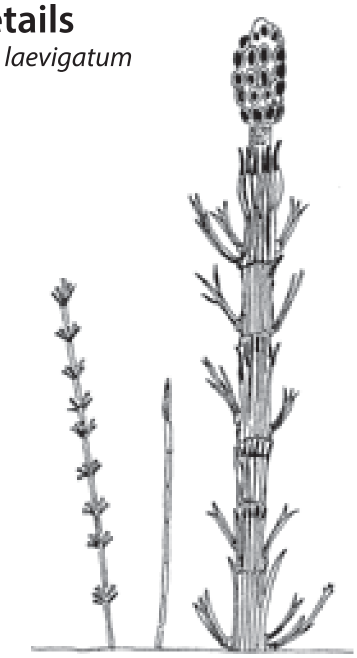


RDI

I am an unusual looking plant. I grow along banks, streams or rivers where my roots can reach the water. My stem is thick and contains tube-like conducting tissues around a hollow center. Solid joints connect my stem segments. Instead of seeds I produce spores from a cone. I have been around for 250 million years and once grew as large as a tree. One of my common names comes from the long striations of my stem and the cone-like tip. Another name comes from the high concentration of silica in my stem, which can be gathered and used to scrub pots.

Smooth Scouring Rush or Horsetails

Equisetum laevigatum

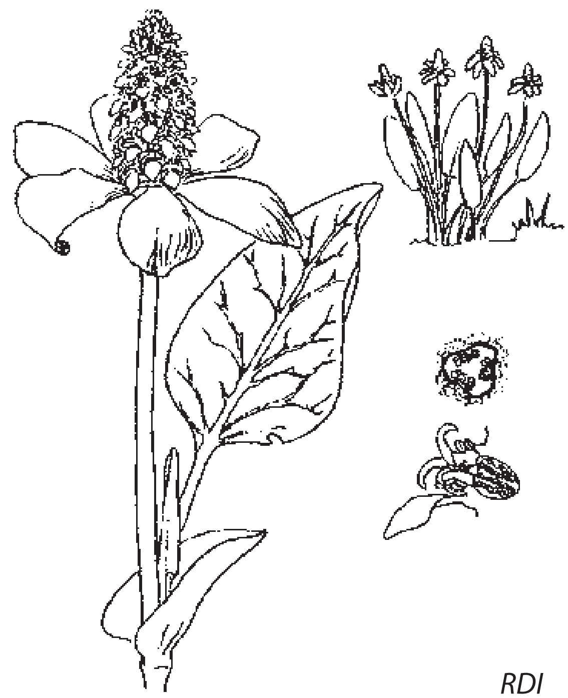


GM

I am known as one of the most used herbs of Spanish and Puebloan cultures. I grow in thick stands where the ground stays moist such as stream beds, low banks of a river or marshes. My broad basal leaves are 3 - 6 inches (7–15 centimeters) long, stand erect and are rounded at the tip. The thick leaves contain lots of moisture and often have a reddish-silvery edge. My flowers form a cone-shaped white spike with six white bracts about the base that look like petals. In the fall my stems, leaves and flowers turn brick red. My leaf stems will sprout roots to form colonies. I smell really strong and earthy. People use me for medicine for inflammation resulting from irritation, injury or infection.

Yerba Mansa

Anemopsis californica



RDI

I grow up to 4 feet (1.2 meters) tall with a stiff, erect, hairy stem. My large delicate yellow flowers open in the evening with four petals and eight large stamens. My leaves are long and lance-shaped with occasional teeth. Hawk moths, bats and bees pollinate me early in the morning. By the middle of the day my bloom has closed, wilted and turned an orange-red color. When my seed capsules mature, they pop open at the slightest touch to propel the seeds away from me. I grow best in moderately dry to moist soil in disturbed areas and open fields.

Hooker's Evening Primrose

Oenothera hookeri

GM

My female flowers form a dense, dark brown sausage-like cluster on a tall stiff stem. The male flowers that grow above this cluster leave a bare stem when they fly away after producing pollen. My seed head fluffs out when my seeds are dispersing. My sword-like leaves are flat, strap-like and spongy and wrap around the stem as they grow. I grow in wet places like marshes and ponds all over the world except where it is really cold. My new shoots taste like cucumbers, my green flower heads can be roasted like corn on the cob. My rootstalks can be eaten raw, roasted over hot coals or dried and ground into meal. Muskrats, geese and elk also eat my roots. American Coots, Red-winged Blackbirds, waterfowl and shorebirds use my leaves as nesting cover.

Broad-leaved Cattail

Typha latifolia

RDI

All of my parts are poisonous, even to the touch. A chemical called atropine and alkaloids, which depress the nervous system, are contained in my system. My large beautiful white, trumpet-shaped flowers open at night to attract sphinx or hawk moths, bats, beetles and bees. During the day I am visited by hummingbirds attracted to my heavily scented flowers. By midday my flower fades to a cream color tinged with lavender, closes and becomes limp. I grow into a large spreading dark green plant up to 6 feet (2 meters) across. My leaves are a dusky green-gray, triangular in shape and strongly veined. When developed my seeds are in a spine-covered 1 - 2 inch (2.5 - 5 centimeters) ball called a capsule that smells musty. My roots are large top-shaped tubers. I grow in deep, well-drained loose soil in eroded arroyos and disturbed areas.

Sacred Datura

Datura wrightii

RDI

You might think I have big, showy flowers, but really those are hundreds of tiny flowers compressed into one flower-like head called a composite. Showy yellow to orange ray flowers surround the brown disk flowers that produce my seeds. My seeds are eaten by birds, squirrels, and even people. I am also used in making soap and paint. My heavy, stiff, hairy and rough stalk can grow up to 10 feet (3 meters) tall. My leaves are alternate and simple, rough and hairy, oval to heart shaped with toothed edges. Sometimes I have one very large flower head filled with nutritious seeds. Other times I produce many branches covered with flowers. Ladybugs, black ants, aphids and bees find food in my flowers and in turn are stalked by spiders and praying mantis. I provide erosion control by growing in places where soil is disturbed and grass is not competing for nutrients.

Sunflower

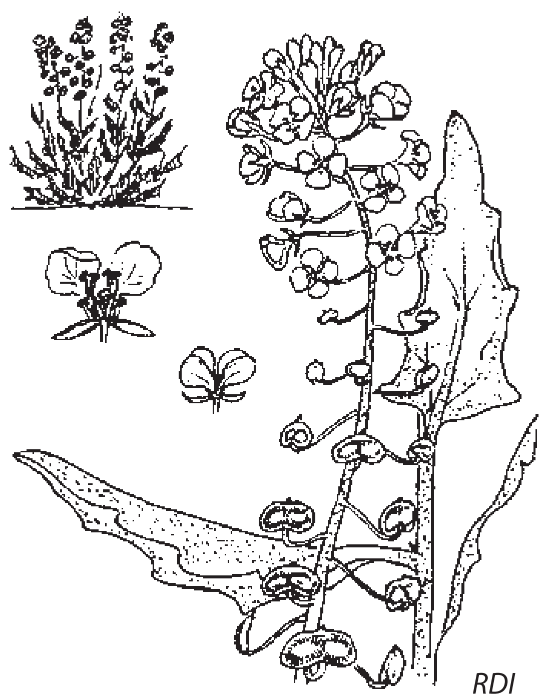
Helianthus annuus

RDI

My genus name means "two shields" in Greek. My fruit pod resembles a pair of round shields placed side by side. Others think this fruit looks like pair of old-fashioned eyeglasses. I am an erect annual herb with the characteristic four petals, four sepals and four anthers of the mustard family. I like open, sandy soil of disturbed areas. I grow 10–12 inches (25–30 centimeters) tall. As I grow I keep producing flowers at the top of my stem. Descending the stem one can observe various stages of ripening seeds; the first blooming flowers are the mature seeds at the bottom of the stem.

Spectacle pod

Dimorphocarpa wislizeni

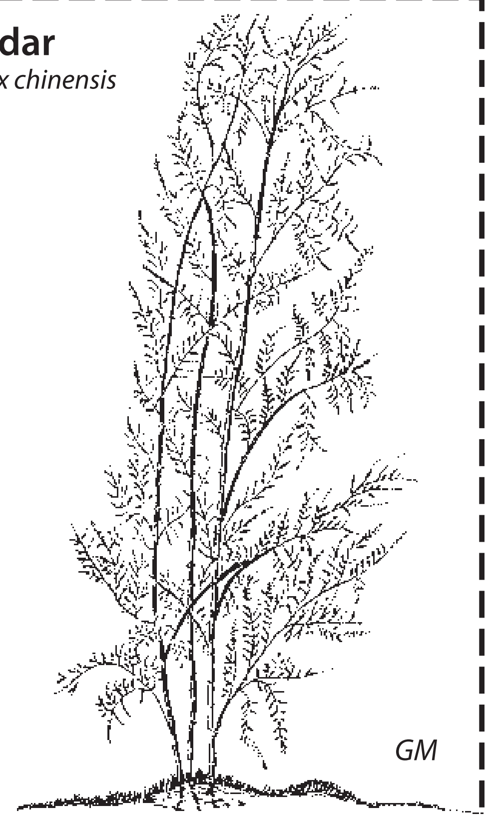


RDI

I have tiny green scale-like leaves and long narrow clusters of tiny pink blossoms. Birds and mammals use my branches for nesting and cover. Honeybees drink my nectar. I am known as a phreatophyte (free-AT-oh-fight) or a well plant because I have deep roots that drink a lot of water from the sandy soil. Where I grow, the soil is salty. Not only can I tolerate salt, but my leaf scales concentrate salt from soil and deposit the salt on the leaf surface. Each fall my leaves turn golden orange then fall to the ground. As my leaves decompose, the soil becomes saltier. My ancestors came from southern Europe or the Mediterranean region.

Saltcedar

Tamarix chinensis



GM

I come from China, but now I make my home in the Southwest, too. My huge compound leaves grow on stout twigs, and the oily glands on my leaves have a disagreeable odor. Clusters of my small yellow-green flowers bear fruits with dry creamy-pink wings. I am a survivor that can grow in very difficult conditions, such as near sea level or in very high mountains. I send up suckers from my roots, which form a thick grove of trees. My name comes from my height that reaches to the sky.

Tree of Heaven

Ailanthus altissima

RDI

Bees love the nectar from my tiny white flowers in the summer, and in the fall and winter goldfinches eat my seeds. Introduced from Europe, I have been planted in some places to stabilize soil, but I have spread along roadsides and other disturbed areas. As a member of the legume—or pea—family, my roots can enrich the soil by fixing nitrogen. I take two years to produce flowers and seeds and can reach 2 - 6 feet (0.06 – 2 meters) tall. In my first year, I am a tiny clump of leaves. My leaves have three leaflets with serrated—or jagged—edges. In my second year of growth I send up a stalk of tiny, white flowers that produce the nectar honey producers cherish. If cattle eat too much of me they can bloat.

White Sweet Clover

Melilotus alba

RDI

I am a native of Eurasia and was brought to New Mexico to prevent soil erosion, though I am also used in landscaping. Sandy soil suits me fine. In the bosque, I sometimes grow in thick clumps of small trees, and I often have sharp thorns. The top of my lance-shaped leaf is dark blue-green and covered with tiny, soft, star-shaped hairs. So many soft hairs cover the bottom leaf surface that it is silvery white. These hairs help keep moisture in my leaves in the hot sun. Bees collect nectar from my tubular, silvery-yellow, lovely-smelling flowers. My fleshy olive-like fruit is eaten by mice, rock squirrels, grosbeaks, towhees and robins who in turn help spread my seed. Because my fruit stays on my branches long after leaves have fallen, it provides food for wildlife in the winter.

Russian Olive

Elaeagnus angustifolia

RDI

My name refers to my ability to get a head start on other grasses by using winter and spring moisture to grow early in the season. While still young and tender, livestock graze my flat leaf blades, but when I mature I have nasty awns—bristle-like appendages—on my seeds. These awns stick in the animals' mouths if they eat me after I have gone to seed. The awns allow my seed to catch a ride in animal fur or people's socks to travel to a new home. When I reach maturity I dry out or "cure" and become a fire hazard. Because I like to grow in disturbed areas I can dominate an area after a fire. This creates a frequent fire cycle that favors my growth over the native grasses. I am relatively new to America but I now grow in much of the western U.S. I originally came from southern Europe and southwestern Asia.

Cheatgrass

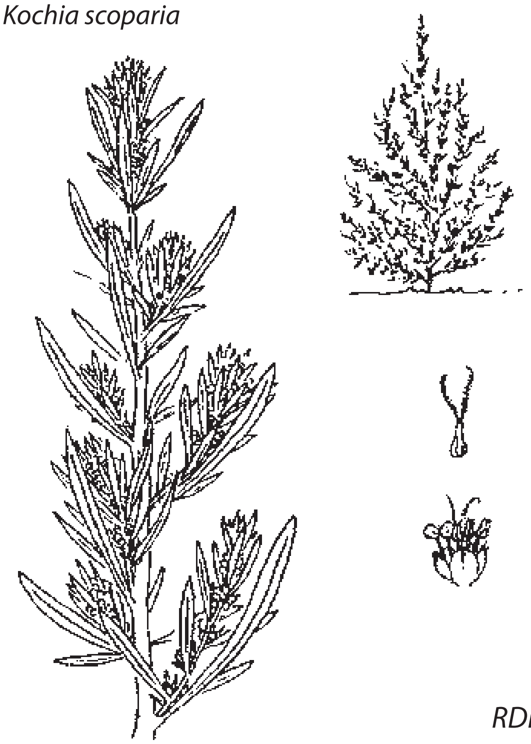
Bromus tectorum

RDI

In the same growing season I spring from a small, wedge-shaped seed to a large herb reaching as high as 6 feet (2 meters) tall. My stems have many round, slender and soft hairy branches. My alternate, lance-shaped leaves have edges fringed with hair and three or five prominent veins. My tiny green flowers are so small you may not notice their dense spikes, but when they bloom, they cause allergies in lots of people. I grow in cultivated fields, gardens and disturbed areas in the bosque where the soil has been disturbed. Birds and mice eat my dull brown seeds. Livestock will eat my leaves, but too many causes an upset stomach. An invasive species from Asia, I have spread all through the United States.

Kochia

Kochia scoparia



RDI

17. Working Water

Agriculture Along the River

Description: With a concentration on the agricultural aspect of the Middle Rio Grande Valley, students focus on creating an irrigation system on the "River of Change" model, expanding on and exploring human influence on the Rio Grande created in the Rio Manso river model.

Objectives: Students will understand:

- one of the main human uses of the river, agriculture;
- the physical characteristics and layout of an agricultural district;
- science and engineering elements in an irrigation system; and
- impacts of agricultural system on the bosque ecosystem.

17. Working Water

Grades: 2–12

Time: initial materials preparation about 30 minutes; another hour to assemble the river, learning where each component goes and how it affects the river system

Subjects: science, social studies

Terms: *acequia, check, dam, ditch, gaging stations, high-line canal, irrigation district, lateral, real-time data, riverside drain, suspended sediments, turnout*

New Mexico STEM Ready! / Next Generation Science Standards

NGSS DCIs and New Mexico State Performance Expectations

5.ESS3.C Human Impacts on Earth Systems

5.PS2.B Motion & Stability: Forces & Interactions

MS.ESS 3.C (MS-ESS3-3 NM) Human Impacts on Earth Systems

MS.ETS2.B (MS-ESS3-3 NM) Influence of Engineering, Technology & Science on Society & the Natural World

NGSS CCCs

Cause & Effect: Mechanism & Explanation; Systems & System Models

NGSS SEPs

Asking Questions & Defining Problems; Developing & Using Models; Constructing Explanations & Designing Solutions*; Obtaining, Evaluating & Communicating Information*

Materials:

- River model set up as Rio Manso. It helps if there is something underneath the model so students can see a slope from foothills to river, and imagine the force of gravity helping the irrigation system work.
- One copy of Working Water student cards
- Scissors
- Envelopes or sandwich bags to hold the pieces and information cards
- Colored pencils or markers (optional)
- Material (listed by color) for various waterways:
  - Rectangular piece of paper or felt for the diversion/utility dam; cut at least the width of the river
  - Two long strips of light-blue fabric or ribbon approximately the length of the river for the high-line canal (these are in addition to the strips or flagging used in "Changing River" to represent the drains alongside the levees described below)
  - Eight shorter strips of blue fabric or yarn for the laterals, acequias, and ditches; they should be about one-fourth the length of the river
  - 20 or so circles, about an inch in diameter, for turnouts
  - Trapezoids or rectangles to represent checks
  - Two long thin strips of fabric the length of the river for the river-side or interior drains (or use the Rio Manso drains)
  - Six to eight small cylinders, cups or film canisters for the gaging stations
  - Distinctive yarn to outline the conservancy district's boundaries

Background:

Irrigation districts, or conservancy districts, are groups of farmers who have come together and pooled their resources so as to reduce the time, money and effort required for profitable irrigation-based agriculture. Instead of trying to maintain their own individual ditches and diversion structures and manage their own allotments of water, farmers can form an irrigation district that is responsible for all the aspects of irrigation for an agriculture community. These aspects can include ditch maintenance, water delivery scheduling, system improvements, water managing and possible legal actions, to name a few. Typically, taxes and water delivery fees are collected by the irrigation district for these uses. The benefit of an irrigation district is obvious in a place like the Middle Rio Grande Valley. It is much more efficient for 10,000 individual farmers to work together, as they do here, than for each one to work on his or her own.

The major purpose of an irrigation district is to efficiently deliver water from a given river to farmers who have water rights on that river. Irrigation districts use gravity as the key force to move water efficiently. Gravity is the force that one body, the earth, has on a second body, in this case water. The important idea to remember here is that the force of gravity on earth pulls all objects towards the center of the earth, and thus always pulls downhill. This being the case, irrigation districts can use gravity to their advantage to convey the water to the desired fields. **Diversion dams**, the structures that divert water from the river, are located at the highest point in the district. Diversion dams feed high-line canals, which are the major artery of the irrigation district. **High-line canals** tend to follow the highest points in the valley that are possible while the water is still flowing downhill, so that as much land as possible can receive water. **Laterals, ditches** and **acequias** branch off the high-line canals and run downhill towards the farmer's fields. Often a farmer will have a personal ditch that delivers water to particular fields the farmer irrigates. These also move water via gravity. In general, all the ditches in an irrigation district drop in elevation more slowly than the river from which the water came. This way, water that is not used by the farmers can return to the river downstream via the force that originally removed the water.

Sometimes the level of water at a particular point in a ditch is too low to feed a turnout to an offshoot ditch. A **turnout** is basically a pipe coming off a ditch which can be open and closed as is needed. This problem is easily solved by the use of a **check** structure. A check is a miniature dam that can be put in place and removed as needed. By placing a check in a ditch that would otherwise have a water level too low to feed a turnout, the level of water above the check will rise and eventually force water into the desired turnout. This is a major way the irrigation engineers can manipulate gravity.

The lowest part of the system are the drains. These lower the ground-water level so that irrigation water will move through the soil and away from plants' roots. An analogy is a house plant in a pot. There is always a hole in the bottom of the pot for excess water to drain out so the roots don't get saturated. Drains in irrigated lands flow into the river, returning water to the Rio Grande.

Irrigated agriculture has been going on in the Middle Rio Grande Valley since the 1600s. The Middle Rio Grande Conservancy District (MRGCD) was formed in 1923 combining more than 70 individual community acequias, or small irrigation districts. An entirely new irrigation network was created to better irrigate the land in the Middle Rio Grande Valley. The MRGCD has four diversion dams (Cochiti, Angostura, Isleta and San Acacia) and more than 1,200 miles (1,920 km) of ditches. The district encompasses about 300,000 acres (120,000 ha) of total area. The MRGCD has rights to about 130,000 acres (52,000 ha) of irrigable land, which means that not every acre in the district is irrigable. For example, the district owns almost all of the bosque, but does not irrigate it. Often, as is the case in Albuquerque, the MRGCD lets other agencies manage their lands. Albuquerque Open Space manages the bosque between the Sandia and Isleta Pueblos. The MRGCD is an agency of the State of New Mexico, and thus has a governing board of directors who are elected in local elections. The MRGCD has its own tax base with which to run its operations.

Procedure:

- Begin with a **KWL** activity. *What do the students **Know** about irrigation? What do they **Want** to know about irrigation?* After the activity, ask *What have they **Learned** about irrigation?* **(Asking Questions & Defining Problems)**

- Discuss students' experiences with irrigation, ditches, etc. *Do their families irrigate? Do they walk along ditches in the valley? What do they know about the flow of water and irrigation? What do they notice about how the water flows in the ditches and drains? How does it compare/contrast to the flow of water in the Rio Grande?*

  What causes rivers to flow?(Gravity) **(5.PS2.B)**

  How do many farmers in the valley irrigate their fields? (From ditches. Some use pumps to bring up ground water, but our focus will be those who use ditches/acequias/laterals to irrigate.)

  What powers the system of ditches and drains? (Gravity) **(5.PS2.B)**

  Making use of the laws of gravity, irrigation water is distributed throughout the valley. Remember as you work on this activity that water does not flow uphill!

  Where would you place the high-line canal? Think about how to use gravity to water fields. (You want to keep the canal along the far edge of the mesa, so it slowly flows downhill. This way you can use gravity to drain into fields toward the river.)

- Think in terms of Systems (see Appendix K). The network of acequias and ditches forms a system to irrigate farmers' fields. *What are the boundaries, components, interactions, inputs and outputs, and properties of this system?* **(Systems & System Models)**

Start with the Rio Manso model set up

- Divide the class into eight groups and pass out one Working Water card and appropriate items to each group.
- Have students read the cards and place their items on the Rio Manso model when instructed to do so.
- Tell the students to place items on the model in the order given below. Each group should describe what they have placed to the entire class and why they chose to place it where they did.
    - irrigation district
    - diversion dam (at the most upstream location in the district)
    - high-line canal (take in the widest section of the valley to maximize available farmland)
    - lateral ditches and acequias
    - farm fields
    - turnouts for fields
    - check dam to make turnouts work
    - gaging stations where you want to know how much water is being used (at the diversion and other places)
    - drains if they are not already in place

Discussion Questions / Assessment:

Look back at the KWL charts. *What have students **Learned**? What additional questions do they have?*

Have students think about these ideas:

How has agriculture affected the Rio Grande Valley? **(Cause & Effect)**
How have farming practices changed over the last century?
What engineering projects have been built to provide water for irrigation for farmers?
What engineering projects protect our communities from flooding?
What engineering projects help farmers conserve water? **(5.ESS3.C; MS.ESS3.C; MS.ETS2.B)**

Extensions:

- Challenge students to build their own gravity-driven water system (they cannot use a running hose for power!) A tub of water could be their source. They could devise a system to divert runoff water from a roof or parking area to water native landscaping. **(Constructing Explanations & Designing Solutions)**
- Students can research traditional agricultural practices and compare those to more modern agriculture. What are advantages or disadvantages of each system? Have students present their findings using posters, written papers, or other formats. **(Obtaining, Evaluating & Communicating Information)**
- Oral history extension: have students talk with elders about agriculture and specifically about irrigation methods. Students may present their findings using posters, written papers, or other formats. **(Obtaining, Evaluating & Communicating Information)**

NGSS Connections to Working Water: Disciplinary Core Ideas

[Middle School details in Appendix K]

5.ESS3.C Human Impacts on Earth Systems *Human activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, ocean, air and even outer space. But individuals and communities are doing things to help protect Earth's resources and environments.*

Humans have made many changes to the Rio Grande Valley, some of them to help farmers get dependable water for their crops. Diversion dams direct water from the river into highline canals and irrigation ditches; deep trenches called drains ensure fields are not water-logged. Levees keep the river from flooding homes and agricultural fields. Water in ditches may help cottonwoods and other native plants grow in places away from the river. While flood irrigation is common in the valley, farmers typically have their field laser-leveled, which reduces water use.

How has agriculture affected the Rio Grande Valley, including the local floodplain ecosystem?
How have farming practices changed over the last century?
What engineering projects have been built to provide water for irrigation for farmers?
What engineering projects or agricultural practices help farmers conserve water?

5.PS2.B Motion and Stability: Forces and Interactions; Types of Interactions *The gravitational force of Earth acting on an object near Earth's surface pulls that object toward the planet's center.*

The force of gravity acts on water on the Earth's surface, resulting in the movement of water "downhill", toward the center of the Earth. This drives the flow of rivers and the movement of water in irrigation ditches. Farmers use this simple but powerful force to irrigate their fields!

What causes rivers to flow?
What powers the system of ditches along the Rio Grande?

Acequia Terms

Acequia: (n) a hand-dug, gravity-fed, canal that diverts water from a stream or other natural water source to irrigate fields, orchards and gardens

Acequia madre: (n) literally "mother ditch" this is the main canal that takes water from the river and divides into each acequia

Atarque: (n) a temporary dam built across a river to divert water into the acequia madre

Compuerta: (n) a headgate that regulates and divides the flow of water

Desagüe: (n) a drainage ditch that channels surplus irrigation water back into a stream

Limpiar: (v) to clean, spring cleaning of the acequias, limpia: (n) community cleaning event

Lindero: (n) also known as sangria, a lateral canal that channels water from the acequia madre to individual properties

Mayordomo/a: (n) a ditch boss who allocates water and oversees canal maintenance

Milpa: (n) a plot of cultivated land used for growing maize

Parciante: (n) a ditch member/irrigator, who works the acequias

Presa: (n) an out-take or diversion dam that diverts water from a stream or other natural water source to move it down- hill via the main canal

Regar: (v) to irrigate

Repartimiento: (n) the partitioning or dividing of waters between ditches that share the same stream or among the parciantes within a single acequia

Sangria: (n) also known as lindero, a lateral canal that channels water from the acequia madre to individual properties

Tiempos: (n) a rotating period of time in which ditch water is allocated

El Agua es Vida, Acequias in New Mexico, Loan Kit Teacher's Guide. Grochowski, A.L. Maxwell Museum of Anthropology, University of New Mexico. 2019.

Working Water Cards

Diversion Dam

A diversion dam is a restrictive structure that is built in a river or waterway so that water can be diverted into irrigation canals for agricultural use. Dams have many uses and not all dams are the same. An agricultural diversion dam typically does not create a reservoir behind it. Diversion dams reduce the flow of the river below the dam structure, trap sediment, and sometimes act as barriers to movement of biological organisms.

- Place the dam at the top of the river system where the high-line canals begin.

High-line Canal

A high-line canal (called an acequia madre (a-SAY-key-a MOD-ray) in northern New Mexico) is the main artery of the irrigation district. It is the large channel that carries water from the diversion dams on the river out across the valley floor by the force of gravity. High-line canals usually fan out from the river and move to the highest points in the valley that are possible while still having the water flow downhill. This way land that is a good distance from the river can still receive water. Once away from the river, the high-line canal usually runs parallel to the river. The high-line canal feeds smaller channels called laterals and acequias.

- Use the lightest blue ribbon or yarn to show the high-line canal.

Lateral, Ditch, and Acequia

These are all terms for smaller channels that spread out like a spider's web from the high-line canal. Typically farm land will be irrigated directly from one of these channels. Larger farms may also have many small channels to deliver water to individual fields. All of these names are interchangeable depending on the local tradition. Note: the term acequia (a-SAY-key-a) can be applied to an actual channel, but is also the term used for the small group of farmers who manage a small irrigation district. The term tends to be used in historical contexts and in upper watershed areas. Farmers' fields are usually clustered around these channels. Remember that gravity is needed to move the water, so the field should be lower than the acequia.

- Use blue yarn to show the laterals/ditches/acequias.

Turnout

A turnout is an irrigation structure that allows a farmer to pour water on a field from a lateral, ditch or acequia (a-SAY-key-a). Often a turnout is located above a check (mini-dam). Turnouts should be placed in irrigation channels where fields are located. A single field usually has multiple turnouts.

- Use small circles to represent the turnouts.

Check

A check is a mini dam on a high-line canal or lateral that causes the water upstream to build up, thus forcing it through turnouts into laterals or onto farmers' fields. Typically, there must be a check for a turnout to function properly.

- Place a check just downstream from any lateral on the high-line canal and a check just below each turnout to a field on a lateral.

River-side Drains

River-side drains (interior drains) closely follow the contours of the river and serve to lower the water table and collect groundwater, which is eventually returned to the river. Although they are also used by agriculture, the river-side drains' main job is to collect excess groundwater and lower the water table in the valley so it is not just a big swamp. They are also called "clear ditches" because the groundwater they collect is free of suspended sediments. These drains generally begin just after the diversion dams and gradually increase in size the further downstream they go. Like levees, they tend to confine the bosque within them. These may already be in place with the Rio Manso setup.

- Place the river-side drains just outside the levees.

Gaging Station

Gaging stations are used by hydrologists for continuous measurement of flows in both the river and the irrigation channels. Older models use physical recording devices to record flow levels over time, while newer radio and satellite-based gaging stations provide real-time data to be used in managing river and irrigation operations. Typically only large canals and drains, as well as the river, have gaging stations. A good rule of thumb is "the scarcer the water, the more gaging stations."

- Place gaging stations near the banks of major waterways and critical junctions in the irrigation system.

Irrigation District

An irrigation district, like the Middle Rio Grande Conservancy District, consists of citizens who live in the river valley on land that has the possibility of being irrigated. Not all land in the irrigation district actually receives water, but all residents in the district's boundaries pay taxes and can vote for the district's governing board. Those who receive water pay only a delivery fee because, if they still own their land's water rights, then they legally own the water. The irrigation district should include any land that can be watered via gravity.

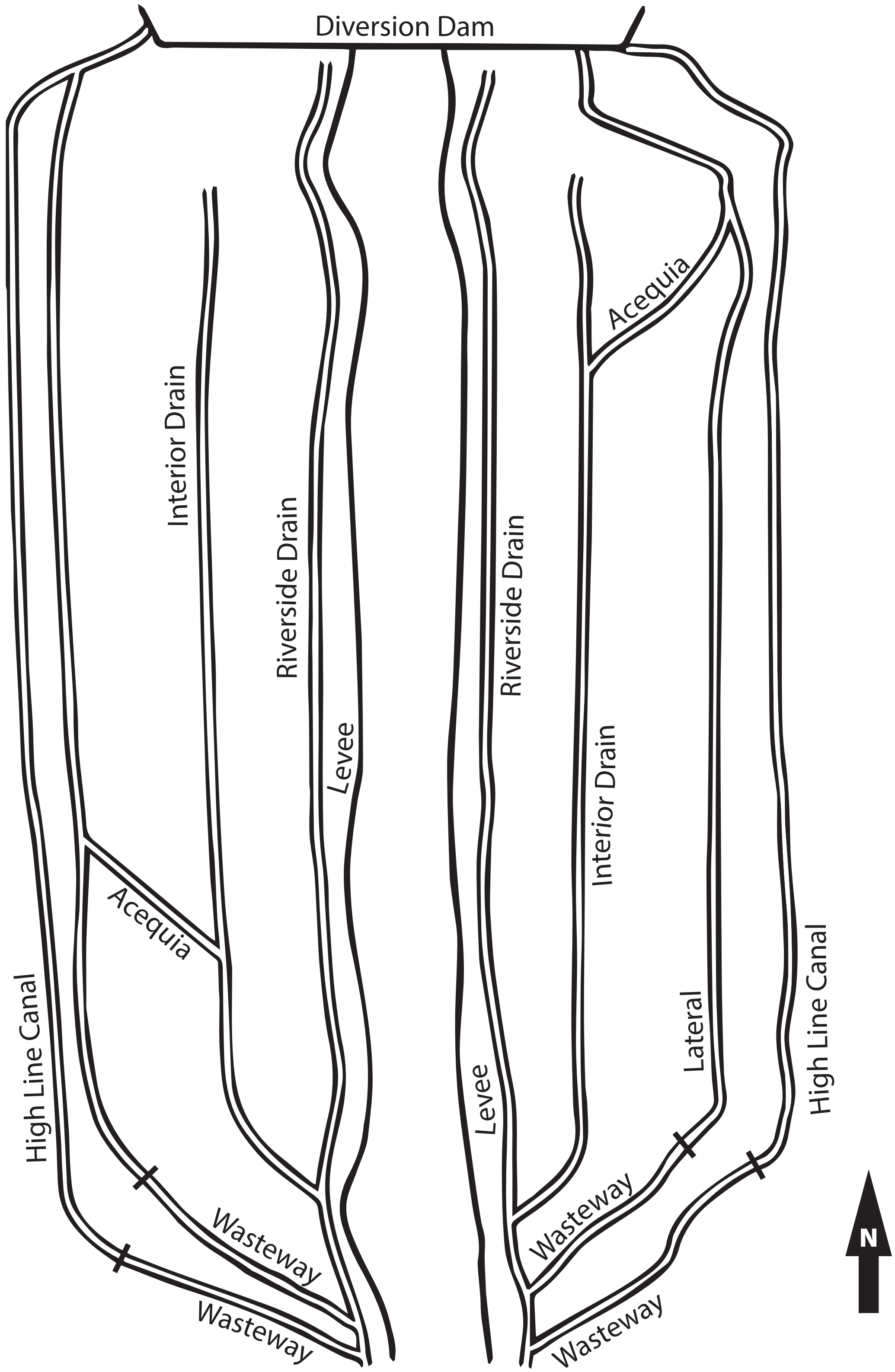
- Use thin black yarn to outline the irrigation district's boundaries.

A drain in the valley lowers the groundwater levels.
Photograph by Mark Higgins

A diversion dam of the Middle Rio Grande Conservancy District near Algodones.
Photograph by Letitia Morris

The metal structure on the left is a check. When it is closed the water in the high-line canal or lateral builds up to a level that will flow through the turnout, shown at lower right, into a farm field or smaller ditch.
Photograph by Anders Lundahl

Schematic of Middle Rio Grande Conservancy District Water System



18. Bosque Chaos

Description: By the roll of dice, students use the "Changing River" model to see how chance influences natural and human-caused changes in the bosque.

Objective: Students learn to recognize the natural processes for change and change due to human activities.

Materials:

- "Changing River" model, first set up as Rio Bravo
- Dice
- Bosque Chaos component cards for Rio Bravo, Rio Manso and Rio Nuevo

Background: The Rio Grande drains from a large area, called its **watershed**. Snow throughout the winter builds up in the mountains of southern Colorado and New Mexico and drains into the river in the spring. Before major human alterations, the river rose each spring when the snows melted, carrying a huge amount of water to the Gulf of Mexico. Some years there would be tremendous flooding, in other years, mild overbank high-water levels, or perhaps simply a rise in groundwater levels. In a large flood, the river often changed its course, moving its channel to another location in the floodplain. In the summer, the water level dropped until the summer storms brought more rain to the area. With this cycling of high water to low water, some plants survived and some did not. Features along the river also changed. During a flood, sandbars could be washed away or deposited. The river channel could change course leaving oxbow lakes or dry channels. A variety of factors influence what might happen at a given location at any time. In this activity we use dice to represent these chance aspects of flood dynamics.

Human alterations have decreased flooding and encouraged a long, narrow forest without a diversity of age groups. Fewer young cottonwoods survive each year and wetlands have become rare. Now managers are working to improve the health of the ecosystem to maintain or reinstate as many aspects of Rio Bravo as possible. Complex environmental conditions beyond the control of humans, however, still play an important role in what happens to a particular element of the bosque.

18. Bosque Chaos

Grades: 5–12

Time: one hour

Subject: science

Terms: *channel, erosion, meander, nutrients, overbank flooding, oxbow, perennial, sandbar, saplings, sediment, seedlings, watershed*

New Mexico STEM Ready! / Next Generation Science Standards

NGSS DCIs

3.LS2.C Ecosystem Dynamics, Functioning & Resilience
3.LS4.C Adaptation
3.LS4.D Biodiversity & Humans
3.ESS3.B Natural Hazards
4.LS1.A Structure & Function
4.ESS2.A Earth Materials & Systems
4.ESS3.B Natural Hazards
5.ESS3.C Human Impacts on Earth Systems
MS.LS2.C Ecosystem Dynamics, Functioning & Resilience
MS.ESS2.C The Roles of Water in Earth's Surface Processes

NGSS CCCs

Patterns; Cause & Effect: Mechanism & Explanation; Scale, Proportion & Quantity; Systems & System Models; Energy & Matter: Flows, Cycles & Conservation; Structure & Function; Stability & Change

NGSS SEPs

Asking Questions & Defining Problems; Developing & Using Models; Constructing Explanations & Designing Solutions; Engaging in Argument from Evidence; Obtaining, Evaluating & Communicating Information*

(* indicates extension activity)

Procedure:

- Have students add to KWL charts—*What do they* ***Know****? What do they* ***Want*** *to know?* And then, *What have they* ***Learned***? at the end of the activity. These questions will help drive the learning as they work through the lesson on the question:

  How does a river flood? What effect does spring flooding have on the bosque ecosystem?
  (Asking Questions & Defining Problems)

- As with the "Changing River" activity, you can use the lens of Systems to learn about the role of chance in the bosque ecosystem (see Appendix K). This activity builds on the Changing River activity to model the floodplain ecosystem over a large spatial scale. **(Systems & System Models; Developing & Using Models)**

Section A: Rio Bravo

- Set up the river model as Rio Bravo (see "Changing River" in this chapter).
- The annual flood pulse, created by high spring runoff, brings energy into the river system. With the energy from the increased flow, changes can occur. *What kinds of changes can the energy of the flooding river bring to the bosque ecosystem and to the river channel?* Brainstorm the types of changes that might be expected. **(MS.ESS2.C; Energy & Matter)**
- Pass out dice to students—one per student or, if there are not enough dice, give one to each group of students or designate one dice-roller for each round of the game.

- Pass out the Bosque Chaos component cards for Rio Bravo and have students find an area on the model that fits the description on their cards. Features described on change cards are: Mature Cottonwood Tree, Cottonwood Sapling, Seedlings on a Sandbar, Cattails (Marsh), Native Riparian Shrub, Grassy Meadow, Bare Sandbar, Riverbank, Active River Channel. Students may need to alter the model to fit their cards. Depending on the size of the model, you may want to have the students take turns.
- Ask students to think for a minute, *What types of changes might happen to your model element if there were a large flood?* Have the students read the cards. Explain that it is easier to predict these changes on a larger scale, such as "if there is a flood, some sandbars will be washed away," but much harder to say, "if there is a flood, this sandbar will be washed away."
- Tell the students it is late spring in the river valley. There was heavy snowfall this past winter, and now the melted runoff is coming down from the mountains. The students will roll the dice to determine how their specific feature is changed by the flood. They should now manipulate the model to reflect the change indicated on the card for the number they rolled.

Note: Students will have to work cooperatively to change other components on the river to accommodate each change.

- Have students explain how the river is different from before the flood. *How is it the same?* Have students exchange component cards, select a new feature on the model, and repeat another year's flood. Repeat this exercise as time and interest allow. *What patterns can the students see? Does that feature exist somewhere else on the model after the flood?* **(Patterns)**

Rio Bravo Discussion Questions:

Along Rio Bravo, in what ways does water change habitats in the floodplain?
(4.ESS2.A; MS.ESS2.A; MS.ESS2.C)

What types of changes are naturally part of the floodplain ecosystems?

In what ways are bosque plants adapted to these changing conditions? What physical characteristics help these plants to survive and grow under variable natural conditions?
(3.LS2.C; 3.LS4.C; 4.LS1.A; MS.LS2.C; Structure & Function)

What patterns can you see for Rio Bravo over time (what natural cycles were present temporally?)

How did flooding create random changes in spatial patterns observed along the river?
(Patterns)

What type of natural hazard occurred along the river before humans made changes?
(3.ESS3.B; 4.ESS3.B)

How is snowfall in the mountains related to flooding in the bosque?

How does the amount of mountain snow affect plants and animals living in the floodplain?
(Cause & Effect: Mechanism & Explanation)

Consider the natural annual cycle of the river.

How did habitats along the floodplain change naturally in Rio Bravo?

How did the floodplain change over time?

How did the floodplain change spatially?

What caused these changes?

How was stability present over time and space?

(4.ESS2.A; MS.ESS2.A; MS.ESS2.C; Stability & Change; Scale, Proportion & Quantity)

Section B: Rio Manso

- With the river set up as Rio Manso (which may be on a different day), repeat this activity using the Rio Manso component cards. Explain that runoff from the Rio Grande watershed is now held by dams in lakes. Therefore, many of today's changes along the bosque are due to the absence of annual flooding. Ask students to explain some of the kinds of changes that are different and changes that are similar between Rio Bravo and Rio Manso.

Rio Manso Discussion Questions:

How have humans altered this system? **(5.ESS3.C)**

What new changes are faced by these organisms, and how do they adjust? **(3.LS2.C; MS.LS2.C)**

Organisms may adapt to changes that occur over long time periods, but often are unable to make adjustments to relatively recent changes. In geologic time, the human-caused changes to the river and floodplain are very new.

What new conditions have been created by human-caused changes?

Are these organisms able to adapt to these human-caused changes along the river? How are they affected? **(3.LS4.D)**

In what ways did humans reduce the impact of flooding on human settlements?

(3.ESS3.B; 4.ESS3.B)

The floodplain naturally changed over time and space with Rio Bravo. Adding dams and channelizing the river affected the Rio Grande's flow and changed the distribution of energy in the system.

How were the natural dynamic spatial and temporal patterns changed by humans?

How did those changes affect the bosque?

How did the distribution of energy change?

(Scale, Proportion & Quantity; Energy & Matter: Flows, Cycles & Conservation)

Explain how random chance can influence the distribution of floodplain habitats.

Explain how human changes have affected the natural patterns of flooding and how this affects floodplain habitats. **(Constructing Explanations & Designing Solutions)**

Section C: Rio Nuevo

- Now repeat using the Rio Nuevo component cards. In this version land managers are working to improve the health of the bosque ecosystem. Ask students to explain some of the changes that are different and other changes that are similar to the Rio Bravo and Rio Manso changes.

Rio Nuevo Discussion Questions:

What changes did humans make along the Rio Grande to promote agriculture and allow settlement along the floodplain?

How did those human alterations affect the bosque, and how could they be modified to allow a more natural, dynamic system?

(5.ESS3.C; Constructing Explanations & Designing Solutions)

Assessment:

- The river model is used to show how the role of chance has changed among the three different river systems. Students can create their own models of the bosque under the three different river conditions (make posters, 3-D model, video, photos, etc.) and show how the role of chance has changed across these systems. **(Developing & Using Models)**
- Write a Claim, Evidence, Reasoning statement that:
    - Explains the role that random chance played in determining the distribution of floodplain habitats along Rio Bravo.
    - Explains the effect that human alterations have had on the natural patterns of flooding and how this affects the distribution of floodplain habitats along Rio Manso.
    - Explains the role that land managers can play in restoring the health of floodplain ecosystems along Rio Nuevo, and reintroducing aspects of the natural patterns that occured along Rio Bravo. **(Constructing Explanations & Designing Solutions; Engaging in Argument from Evidence)**

Extensions:

- Combine this activity with "Who Lives Where?" in this chapter. Locate the animals on the model. After each round, explain how each animal fared through the flood or other change.
  Which animals had to move, or could not survive?
  Which animals were able to find new habitat?
  How do improvements from land managers benefit native animals in Rio Nuevo?
  (3.LS4.C; 4.LS1.A; Structure & Function, Engaging in Argument from Evidence)
- Students can investigate how changes to the natural river system, such as the installation of dams and levees and the lowering of the water table, affect the distribution of habitats across the floodplain. Evaluate the importance of flooding in maintaining the diversity of habitats and the impact of human changes on the system. Share these ideas orally, or by writing letters, flyers, posters or books **(Obtaining, Evaluating & Communicating Information; ELA/ Common Core Standards).**
- Propose engineering solutions to help reintroduce chance into Rio Nuevo.

NGSS Connections to Bosque Chaos - Disciplinary Core Ideas

[Middle School details in Appendix K]

3.LS2.C Ecosystem Dynamics, Functioning and Resilience *When the environment changes in ways that affect a place's physical characteristics, temperature, or availability of resources, some organisms survive and reproduce, others move to new locations, yet others move into the transformed environment, and some die.*

Change is inherently part of floodplain ecosystems. This dynamic nature means that the exact conditions at a given location are often determined by chance. Organisms may adapt to changes that occur over long time periods, but often are unable to make adjustments to relatively recent changes. In geologic time, the human-caused changes to the river and floodplain are very new. Students learn how these changes affect bosque organisms and habitats, and how rapid human changes have further affected the system.

What types of changes are naturally part of floodplain ecosystems?
How do local plants deal with these changes?
How have humans altered this system?
What new changes are faced by these organisms in Rio Manso, and how do they adjust?

3.LS4.C Adaptation *For any particular environment, some kinds of organisms survive well, some survive less well, and some cannot survive at all.*

Bosque plants have evolved to handle variable conditions found along the natural river course. They have characteristics that help them survive in this environment.

In what ways are bosque plants adapted to the changing conditions experienced along the old river, Rio Bravo?

3.LS4.D Biodiversity and Humans *Populations live in a variety of habitats, and change in those habitats affects the organisms living there.*

Although floodplain ecosystems are very dynamic, with frequent changes to habitats occurring at a local scale, native organisms are less able to deal with the types of sudden changes caused by humans.

What new conditions have been created by human-caused changes?
Are native organisms able to adapt to these human-caused changes along the river? How are they affected?

4.LS1.A Structure and Function *Plants and animals have both internal and external structures that serve various functions in growth, survival, behavior, and reproduction.*

Bosque plants have evolved to handle variable conditions found along the natural river course. They have characteristics that help them survive in this environment.

In what ways are bosque plants adapted to the changing conditions experienced along the old river, Rio Bravo?
What characteristics help these species survive and grow under natural conditions?

4.ESS2.A Earth Materials and Systems *Rainfall helps to shape the land and affects the types of living things found in a region. Water, ice, wind, living organisms, and gravity break rocks, soils, and sediments into smaller particles and move them around.*

Water plays an important role in creating floodplain ecosystems. Under natural conditions, the floodplain is constantly changing from the forces of river water. For example, the active channel moves, sandbars are created or washed away, and sediment is deposited in the forest. These changes affect the organisms living there.

Along Rio Bravo, in what ways does water change habitats in the floodplain?
How do floodplain ecosystems change as a result of floods along the river?

3.ESS3.B Natural Hazards *A variety of natural hazards result from natural processes. Humans cannot eliminate natural hazards but can take steps to reduce their impacts.*

Flooding is a natural part of the Rio Grande and floodplain ecosystems. Eliminating flooding has allowed humans to settle in the floodplain.

What type of natural hazard occurred along the river before humans made changes?
In what ways did humans reduce the impact of flooding on human settlements?

4.ESS3.B Natural Hazards *A variety of natural hazards result from natural processes (e.g., earthquakes, tsunamis, volcanic eruptions). Humans cannot eliminate the hazards but can take steps to reduce their impacts.*

Flooding is a natural part of the Rio Grande and floodplain ecosystems. Eliminating flooding has allowed humans to settle in the floodplain.

What type of natural hazard occurred along the river before humans made changes?
In what ways did humans reduce the impact of flooding on human settlements?

5.ESS3.C Human Impacts on Earth Systems *Human activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, ocean, air and even outer space. But individuals and communities are doing things to help protect Earth's resources and environments.*

Human alterations have changed the dynamic nature of the Rio Grande floodplain and altered many aspects of natural habitats (changing from Rio Bravo to Rio Manso). In Rio Nuevo, students learn how humans are able to make new changes that help restore some of the structure and function of natural floodplain ecosystems.

What changes did humans make along the Rio Grande to promote agriculture and allow settlement along the floodplain?
How did those human alterations affect the river and bosque? How could they be modified to allow a more natural, dynamic system?

Rio Bravo Component Cards

Mature Cottonwood Tree

Roll the dice. Follow the 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.

1. The river flows over its banks and floods the area around the tree. Nutrients are increased. The tree is healthy and grows.
2. No flooding near the tree. Nutrients are trapped in the forest floor litter. The tree grows slowly.
3. The river rises but does not overflow its banks. The water table rises. The tree is healthy and grows.
4. The river flows over its banks and floods the area around the tree. Nutrients are increased. The tree is healthy and grows.
5. Severe flooding erodes the bank and knocks the tree over. The tree dies.
6. The river flows over its banks and floods the area around the tree. Nutrients are increased. The tree is healthy and grows.

Rio Bravo

Cottonwood Sapling

Roll the dice. Follow the 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.

1. The main river channel moves away and the sapling continues growing.
2. Beaver cut down the cottonwood sapling.
3. The sapling is bent over by floodwater but survives.
4. It is a dry year, the sapling dies in the summer heat.
5. The main river channel moves away and the sapling continues growing.
6. Beaver cut down the cottonwood sapling.

Rio Bravo

Seedlings on a Sandbar

Roll the dice. Follow the 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.

1. The sandbar is washed away, along with the seedlings.
2. The seedlings remain and the sandbar grows because of sediment being trapped by the plants.
3. The seedlings are buried by sediment and die, resulting in bare sandbar.
4. It is a dry year so seedlings die as the water table quickly drops.
5. The sandbar is washed away, along with the seedlings.
6. The seedlings grow quickly as the high river level drops slowly.

Rio Bravo

Grassy Meadow

Roll the dice. Follow the 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.

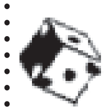
1. The grassy meadow is higher than floodwater and there is no change.
2. The river channel shifts and flows through this area, which now becomes a river channel.
3. A braid or small channel from the river feeds into the meadow, and the meadow changes to a marsh.
4. The grassy meadow is higher than floodwater and there is no change.
5. Over time, large amounts of sediment are deposited in the meadow and cottonwood seedlings germinate and start growing.
6. The river rises but doesn't flow over its banks. Groundwater levels rise. The grassy meadow grows.

Rio Bravo

Native Riparian Shrub

Roll the dice. Follow the 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.

1. The shrub is flooded but enjoys more nutrients and puts on new growth.
2. The flood does not impact the area and the shrub stays the same.
3. The shrub is knocked down by a flood and removed from the area.
4. The flood does not impact the area and the shrub stays the same.
5. The shrub is flooded but enjoys more nutrients and puts on new growth.
6. The shrub is flooded but enjoys more nutrients and puts on new growth.

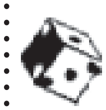


Rio Bravo

Cattails (Marsh)

Roll the dice. Follow the 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.

1. The river rises somewhat in the spring and lowers in the heat of the summer. The marsh area remains healthy.
2. The river rises and changes its channel through the marsh in the spring. There is no longer a marsh at this spot. It is replaced by a river channel.
3. It is a dry year. The marsh dries out and most of the plants die.
4. The river rises somewhat in the spring and lowers in the heat of summer. The marsh area remains healthy.
5. The river rises and changes its channel away from the marsh. A stand of willows (or other riparian shrubs) replaces the marsh.
6. The river rises somewhat in the spring and lowers in the heat of summer. The marsh area remains healthy.



Rio Bravo

Bare Sandbar

Roll the dice. Follow the 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.

1. Cottonwood seedlings start growing on sandbar.
2. Native riparian shrubs (willows) start growing on sandbar.
3. The river rises and the sandbar is washed away.
4. Cottonwood seedlings start growing on sandbar.
5. Native riparian shrubs (willows) start growing on sandbar.
6. The river rises and the sandbar is washed away.

Rio Bravo

Riverbank

Roll the dice. Follow the 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.

1. Beavers and muskrats build homes in the bank of the river.
2. Fast spring currents undercut the bank. Bank slips into river and sediment is washed downstream. Move riverbank farther back from original channel.
3. Willow thicket becomes established, providing stability to the riverbank.
4. River changes course and channel is abandoned. Cottonwood saplings grow on old bank.
5. Fast spring currents undercut the bank. Bank slips into river and sediment is washed downstream. Move riverbank farther back from original channel.
6. Sediments from upstream are deposited next to riverbank. Bank expands to flat sandy beach.

Rio Bravo

Active River Channel

Roll the dice. Follow the 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.

1. The river changes course, leaving the old channel empty.
2. The flood does not affect the channel in this spot.
3. Sediment is deposited as the flood waters drop and a new sandbar forms.
4. The river cuts across an old meander to create an oxbow.
5. The channel grows wider as banks erode.
6. Sediment is deposited as the flood waters drop and a new sandbar forms.

Rio Bravo

Seedlings on a Sandbar

Roll the dice. Follow the 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.

1. Seedlings are swept away by high water, but sandbar remains.
2. It is a drought year. Surface and groundwater levels drop quickly. The seedlings die.
3. Seedlings are repeatedly grazed by cattle and die.
4. Sandbar is covered in saltcedar so no cottonwood seedlings germinate.
5. It is a drought year. The river dries up and groundwater levels drop quickly. The seedlings die.
6. Sediments are trapped by plants so the sandbar grows and the seedling survives.

Rio Manso

Cottonwood Sapling

Roll the dice. Follow the 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.

1. Cattle eat the cottonwood sapling.
2. The river rises, but does not overflow its banks. The groundwater level rises. The sapling has enough water, so continues growing.
3. The cottonwood sapling is killed by a wildfire.
4. Beaver cut down the cottonwood sapling.
5. There is a drought. The water table drops quickly and the sapling dies.
6. Beaver cut down the cottonwood sapling.

Rio Manso

Mature Cottonwood Tree

Roll the dice. Follow the 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.

1. The river level rises but does not overflow its banks. The water table rises. The tree benefits from increased water and grows.
2. There is a drought so no flooding. Nutrients are trapped in the forest floor litter, so tree grows slowly.
3. No flooding in vicinity of tree. Area becomes dry. Fire burns through area and kills mature tree.
4. There is a drought so no flooding. Nutrients are trapped in the forest floor litter, so tree grows slowly.
5. No flooding in vicinity of tree. Area becomes dry. Fire burns through area and kills mature tree.
6. No flooding in the vicinity of tree. Tree becomes weak and dies from insect and disease attacks.

Rio Manso

Cattails (Marsh)

Roll the dice. Follow the 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.

1. Riverside drains were installed to lower the groundwater and allow agriculture. The marsh dries up.
2. Marsh area is filled in to allow new home construction.
3. Riverside drains were installed to lower the groundwater and allow agriculture. The marsh dries up.
4. Marsh is located in an old oxbow of the river. Groundwater along the channel remains high, so marsh remains healthy.
5. Riverside drains were installed to lower the groundwater and allow agriculture. The marsh dries up.
6. Marsh area is filled in to allow the construction of a shopping mall.

Rio Manso

Native Riparian Shrub

Roll the dice. Follow the 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.

1. There is a drought. The water table drops and the native riparian shrub dies. An upland shrub takes its place.
2. The shrub is killed in a wildfire but soon begins to sprout from its roots.
3. The shrub is knocked down by bulldozers constructing a road.
4. There is a drought. The water table drops and the native shrub dies. Non-native shrubs that tolerate drier conditions increase.
5. The river rises but does not flow over its banks. Ground water levels rise and the native shrub grows well with extra water.
6. The shrub is killed in a hot wildfire that is made worse by dead and downed wood in the forest.

Rio Manso

Grassy Meadow

Roll the dice. Follow the 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.

1. Grassy meadow is higher than floodwater and there is no change.
2. A very hot fire burns across greasy meadow. Weedy plants such as cockleburs, kochia (KO-sha) and introduced annual grasses replace native perennial grasses which did not survive the fire.
3. River rises and groundwater increases. Grasses receive more water and grow.
4. Grassy meadow is cleared for agricultural field.
5. Cattle overgraze meadow; upland shrubs invade.
6. Grassy meadow is too high for flood water. Grasses die and are replaced by upland shrubs.

Rio Manso

Active River Channel

Roll the dice. Follow the 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.

1. The river has been stabilized with jetty jacks so the channel is unaffected by higher water.
2. Clear water is released from up-river dam. Water takes on more sediments and cuts the river bed deeper.
3. Saltcedar and Russian olive have grown along riverbank, further stabilizing the channel.
4. The river has been stabilized with jetty jacks so the channel is unaffected by higher water.
5. Clear water is released from up-river dam. Water takes on more sediments and cuts the river bed deeper.
6. There is an extended drought. There is little runoff and the active river channel dries up in the summer heat.

Rio Manso

Riverbank

Roll the dice. Follow the 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.

1. The riverbank is unaffected by the river this year. Bank stays the same.
2. Sediments from upland erosion are deposited next to the riverbank, leaving a broad, sandy beach.
3. Cattle and people walk on the riverbank, causing bank to slide into the river.
4. Beavers and muskrats build homes in the bank of the river.
5. Russian olive trees become established, providing stability to the riverbank.
6. Clear water is released from up-river dam. Water takes on more sediments and cuts river bed deeper. Riverbank becomes higher.

Rio Manso

Bare Sandbar

Roll the dice. Follow the 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.

1. Exotic riparian trees (saltcedar) and cockleburs start growing on sandbar.
2. Cottonwood seedlings start growing on sandbar.
3. Exotic riparian trees (saltcedar) start growing on sandbar.
4. Exotic riparian trees (Russian olive and saltcedar) start growing on sandbar.
5. The river rises and the sandbar is washed away.
6. A dam is built upstream. The clear outflow water picks up sediment and carries the sandbar away.

Rio Manso

Mature Cottonwood Tree

Roll the dice. Follow the 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.

1. There is a drought so no flooding. Nutrients are trapped in the forest floor litter, so tree grows slowly.
2. Managers apply an artificial flood to the forest. Nutrients are increased and the tree grows well.
3. Managers cut down a bank to allow natural flooding in the forest, so the tree grows well.
4. No flooding near the tree. Nutrients are trapped in the forest floor litter, so the tree grows slowly.
5. No flooding in area of tree so area becomes dry. Very hot fire burns through and kills mature tree.
6. Managers remove excess wood from forest, so wildfires burn out and don't kill trees. Tree keeps growing.

Rio Nuevo

Cottonwood Sapling

Roll the dice. Follow the 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.

1. The water table remains high so cottonwood sapling continues to grow.
2. Cattle are kept from river by a fence so sapling continues to grow.
3. Beaver cut down the cottonwood sapling.
4. Students help plant cottonwood poles in a restoration project. The sapling survives.
5. There is a drought. The water table drops quickly and the sapling dies.
6. Cottonwood leaf beetle larvae kill the cottonwood sapling.

Rio Nuevo

Seedlings on a Sandbar

Roll the dice. Follow the 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.

1. Seedlings are swept away by high water, but sandbar remains.
2. Sediments are trapped by plants so the sandbar grows and the seedling survives.
3. It is a dry year so seedlings die as the water table quickly drops.
4. Beavers eat some seedlings, but some remain
5. There is a drought. Seedlings die because the sandbar dries out.
6. Managers create artificial flood and water level drops slowly. Seedlings grow quickly.

Rio Nuevo

Rio Nuevo Component Cards

Grassy Meadow

Roll the dice. Follow the 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.

1. Grassy meadow is higher than floodwater and there is no change.
2. Recent fuels management in adjacent forest keeps wildfire moderate, so native grasses recover after fire.
3. Managers apply artificial flood to the area. Grasses receive more nutrients in floodwater and grow well.
4. Grassy meadow is cleared for an agricultural field.
5. Cattle overgraze meadow and upland shrubs invade.
6. There is an extended drought so the grassy meadow dries up. Upland shrubs invade.

Rio Nuevo

Native Riparian Shrub

Roll the dice. Follow the 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.

1. The native riparian shrub benefits from artificial flooding and grows well.
2. The shrub is killed in a hot wildfire that is made worse by dead and downed wood in the forest.
3. The shrub is cut to build a new bridge.
4. School children help plant new native riparian shrubs.
5. The native riparian shrub benefits from artificial flooding and grows well.
6. Managers remove some excess wood from forest so next wildfire is not severe and the shrub recovers quickly.

Rio Nuevo

Cattails (Marsh)

Roll the dice. Follow the 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.

1. Volunteers help build new wetland, so excellent habitat is provided for wildlife.
2. No funding is available for wetland project and area is converted to a parking lot.
3. It is a drought year, so wetland project is canceled by short-sighted officials.
4. Volunteers help build new wetland, so excellent habitat is provided for wildlife.
5. Constructed wetland is created to treat wastewater from housing development and to create habitat.
6. Potential wetland area is converted to houses.

Rio Nuevo

Bare Sandbar

Roll the dice. Follow the 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.

1. Exotic riparian trees (saltcedar) and cockleburs start growing on sandbar.
2. Cottonwood seedlings start growing on sandbar.
3. Exotic riparian trees (Russian olive and saltcedar) start growing on sandbar.
4. The river rises and the sandbar is washed away.
5. The river rises and the sandbar is redistributed downstream.
6. Native riparian shrubs (willows) start growing on sandbar.

Rio Nuevo

Riverbank

Roll the dice. Follow the 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.

1. The riverbank is unaffected by the river this year. Bank stays high.
2. Managers use bulldozers to lower the bank to allow overbank flooding into the forest.
3. Beavers and muskrats build homes in the riverbank.
4. The riverbank is unaffected by the river this year. Bank stays high.
5. Managers use bulldozers to lower the bank to allow overbank flooding into the forest.
6. People and their dogs walk along the riverbank, causing bank to slide into the river and sediment to move downstream.

Rio Nuevo

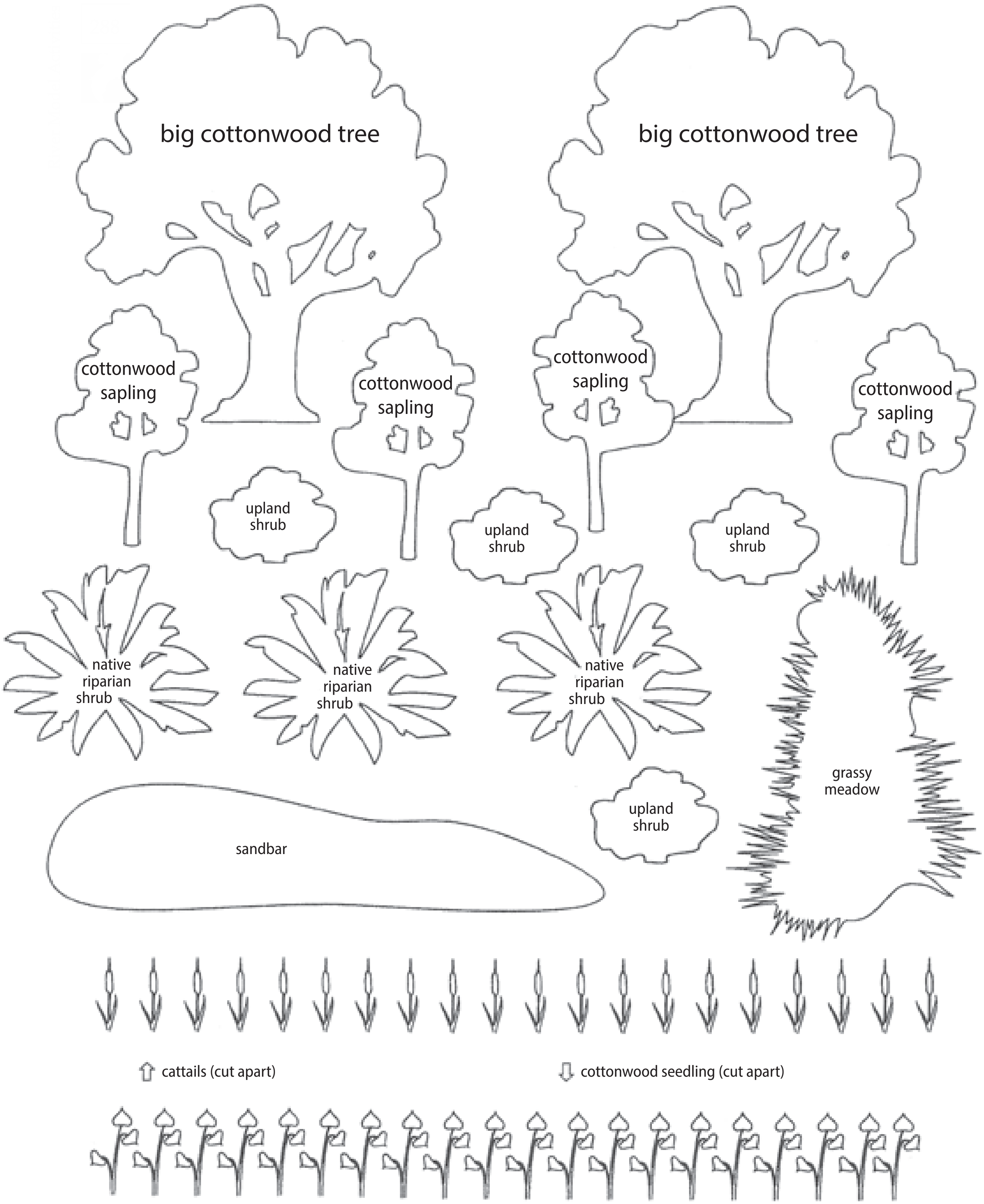
Active River Channel

Roll the dice. Follow the 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.

1. Managers lower the bank to allow flooding into the forest. This moves sediment into the channel and a new sandbar forms downstream.
2. This section of the river has been stabilized with jetty jacks so the channel is unaffected by higher water.
3. Jetty jacks have been removed so the channel moves slightly with higher floodwater.
4. Saltcedar and Russian olive have grown along riverbank, further stabilizing the channel.
5. Managers lower the bank to allow flooding into the forest. This moves sediment into the channel and a new sandbar forms downstream.
6. This section of the river has been stabilized with jetty jacks so the channel is unaffected by higher water.

Rio Nuevo

Rio Bravo Model Pieces: Make Five Copies



Rio Manso Model Pieces: Make Five Copies