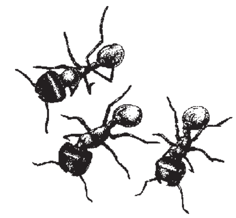
Chapter 5

Meandering Channels: School-based Activities



Activity Number		Page Number
Natural History		
19.*	The Web	301
20.*	Bosque Bugs Boogie	311
21.*	Bosque Survey	329
22.*	Mapping Species Richness	337
23.*	Crane Migration	352
24.*	Invasive Species	366
46.*	Energy in Bosque Ecosystems	386
	Bird Migration in New Mexico	401
47.*	Who Flew Where?	415
48.*	Changes in Bird Populations	430
Geology		
	Geologic History of the Rio Grande Rift	389
25.	Time Line Activity	395
26.	What Is the Rio Grande Rift?	397
27.	WebQuest: Geologic History	407
28.	Porosity and Permeability	415
Water		
29.	Rio Grande Bosque Water Cycle	423
30.	Surface Water Demonstration	432
31.	Watersheds in New Mexico	437
32.	Rio Grande Stream Table	448
33.	How Deep Is the Water Table?	453
34.	Water Budget Activity	467
35.	Interpreting a Hydrograph	477
Human Influence		
	Acequia Culture	487
36.	Change Is All Around Us	490
37.	Aldo Leopold	506
38.	River Stories	521
39.	Bosque Songs	531
40.	If You Owned a Bosque Ecosystem	539

* NM STEM Ready! / Next Generation Science Standards (NGSS) aligned

19. The Web

Interactions in the Bosque Ecosystem

Description: Students choose a plant or animal in the bosque; then, while standing in a circle, they show connections with other plants or animals by passing a string from one organism to another, illustrating relationships in the web of life.

Objective: Students will learn that:

- there are many species that depend on each other in the bosque ecosystem; and
- that the loss of one will affect other species.

Materials:

- Large ball of string
- Bosque animal cards from #15 "Who Lives Where?" activity
- Bosque plant cards from #16 "Who Grows Where?" activity
- Decomposition card from #46 "Energy in a Bosque Ecosystem" activity (optional)

Phenomena: Porcupines are seen high in trees. Birds build nests in bosque trees and bushes. Harvester ants carry seeds. Mosquitoes are annoying but other animals eat them.

Lesson Question:

- *How do plants and animals need each other in the bosque?*

19. The Web

Grades: 3-8

Time: one hour

Subject: science, extensions in language, writing, drawing

Terms: *abiotic, biotic, carnivore, ecosystem, food chain, food web, herbivore, mutually beneficial, omnivore, photosynthesis, Species of Greatest Conservation Need (SGCN), threatened/endangered species, web of life* [Most are in the Glossary - three others are defined in context below]

New Mexico STEM Ready! / Next Generation Science Standards

NGSS DCIs

3.LS2.C Ecosystem Dynamics, Functioning & Resilience
3.LS4.D Biodiversity & Humans
5.LS2.A Interdependent Relationships in Ecosystems
5.ESS3.C Human Impacts on Earth Systems
MS.LS2.A Interdependent Relationships in Ecosystems
MS.LS2.B Cycles of Matter & Energy Transfer in Ecosystems
MS.LS2.C Ecosystem Dynamics, Functioning & Resilience
MS.LS4.D Biodiversity & Humans*
MS.ESS3.C Human Impacts on Earth Systems*

NGSS CCCs

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

NGSS SEPs

Asking Questions & Defining Problems; Developing & Using Models; Engaging in Argument from Evidence*; Obtaining, Evaluating & Communicating Information
(* indicates extension activity)

Background:

Energy from the Sun provides the fuel for most life on the planet. Plants are able to use the sun's energy, through **photosynthesis**, to make their own food. With carbon dioxide and water and the energy provided by the sun, plants make glucose/sugars that provide the energy for growing leaves, stems, flowers, and fruit. Some animals will eat plants to get the nutrition/sugars they need to grow, move, and reproduce (**herbivores**); in turn, other animals will get their nutrition/sugars from eating other animals (**carnivores**); and still others will eat a combination of plants and animals (**omnivores**). Strictly speaking, a "food web" does not include the Sun. Organisms cannot eat the sunlight, so it is not "food"; **sunlight** is the **energy** that allows a plant to make food for itself. A **food chain** indicates the connections between organisms showing what eats what. A **food web** will include multiple species eating another species, and being eaten by many species (i.e., multiple food chains). But in this activity, we are trying to get students to think about any connection between organisms, not only food-related ones. Animals live in **habitats** where they must have **food**, **water**, **shelter**, and the **space** needed to survive. We refer to all such interactions, not just the food chains, as the **web of life**. For example, birds need to perch on things and make nests of material that they don't eat, but without those parts of the habitat, they cannot survive. Some species of mistletoe depend on a bird to eat its berries, fly to another tree, and deposit its seeds there. (This activity focuses on the **biotic** or living components of the system. The **abiotic** or nonliving parts—air, water, soil, temperature, shade, etc.—although also very important, are not a focus of this activity.) Students will model the interactions between organisms in a bosque **ecosystem**. They should think of as many connections as they can between the plants and animals in the bosque when they do this activity. They will begin to see the links among components in the complex web of life.

Procedure:

- Make a KWL chart with your students.

  *What do you **Know** about how living things are connected in the bosque?*

  *What do you **Want** to know about how living things are connected in the bosque?*

  *After the lesson, revisit the chart and ask, What have you **Learned** about how living things are connected in the bosque?* **(Asking Questions & Defining Problems)**

  - *Where do plants and animals get the food they need to survive and grow? What does each species need to survive (i.e., the food, water, shelter, space in the bosque)?* **(Systems & System Models;** see Appendix K)

  An informal assessment, as you start the activity, is to have students design a food chain or a food web based on what they know now:

  - *What is the "Web of Life?"* Think of yourself as some living plant or animal. *What do you need to live as that plant or animal; what food, water, shelter, and space do you need?*
  - Now consider two organisms such as coyote and yerba mansa. *How might they be connected in the bosque web of life?*

  To best do this activity, it helps for your students to be familiar with some plants and animals of the bosque. Some options:

  - Do a walk in the bosque or schoolyard with your students. *What plants and animals do you see? What signs of animals do you find? What are the habitat needs of each plant or animal they have seen? What food does each animal eat?*
  - Make a class list to summarize all observations.
  - Think of food chains and/or food webs from the plants and animals they have seen.
  - Find an online video to introduce your students to the bosque, and, as a class, think of food chains and/or food webs from some of the species they see on the video.
  - Find a video about food chains and food webs in general.
  - Do the River of Change activities #13 "Changing River" and #15 "Who Lives Where?"

  Select an assortment of bosque plant and animal cards so that there is one for each student. Use the pictures of animals from #15 "Who Lives Where?" activity and at least the <u>cottonwood</u> picture from #16 "Who Grows Where"; all are in this *Guide*. Include an insect, such as the <u>mosquito</u>. Use the <u>Decomposition card</u> from #46 "Energy in a Bosque Ecosystem" activity to address interdependence, how the loss of one species affects the other species, as part of a second round. **(5.LS2.A)**

- Pass out the plant and animal cards. Have all the students stand in a circle and state what plant or animal they are. Then challenge them to make connections between themselves and another plant or animal.

The discussion might go as follows:

All the energy for plants and animals on the Earth comes from what? (the Sun)

What organisms on Earth make use of that energy directly? (plants)

What is the process that plants use to do that? (photosynthesis)

So, let's start with a plant. (Give one end of the string to a plant.)

What eats the plant? (Send the string to an herbivore.)

What eats an herbivore? (Send the string to a carnivore.)

What does each animal consume? What eats it? How are the animal species' needs met in the bosque ecosystem?

Now let's make as many connections as we can think of between species. We want to get beyond just what eats what.

- *Where will its home be?*
- *Does it need a place to perch to find food?*
- *Does it need the droppings of something to fertilize it?*
- *Are any species competing with each other?*
- Add non-living factors to achieve more of this standard (see *Extensions*).
- *What happens when species are competing for food, water, oxygen, or other resources?* For example, many species eat seeds on the ground. Some kinds of insects are competing with birds such as the Spotted Towhee or Dark-eyed Junco for seeds on the ground.
- *What role do predators play in this ecosystem?*

Be creative in thinking of connections. **(5.LS2.A; MS.LS2.A; Energy & Matter: Flows, Cycles & Conservation)**

Pass the string between all the organisms that are connected. Make sure everyone is included. You will have created quite a web!

Continue the activity by asking:

- *What happens when we lose a piece (i.e., one of the organisms in an ecosystem)?*
- *How about the **mosquito**?*
    - I don't like mosquitoes. I would prefer not to be bitten by any more mosquitoes, so I am going to spray pesticides to get rid of them.
    - Mosquito, you shake your string(s) to show that something is happening to you.
    - *Who feels the shaking?* You have been affected by the loss of the mosquito.
    - Now everyone who feels the shaking, shake your strings to pass it on. In this way, the loss of one species is felt by many others; one change in an ecosystem ripples throughout.

In real life, there are many connections between organisms, some of which researchers are just now learning about. Sometimes we find out about the crucial role of a species only when it is too late to do anything to save it.

There are **threatened** and **endangered** species, and **Species of Greatest Conservation Need (SGCN)** so designated by New Mexico Department of Game and Fish, that eat mosquitoes (either mosquito larvae or adult mosquitoes). The **Southwestern Willow Flycatcher** is one of them. They perch on branches in thick stands of willow or cottonwoods and eat flying insects. In the San Juan River, **Razorback Suckers** eat the larvae of aquatic insects like mosquitoes. Adult **Northern Leopard Frogs** will catch flying insects like mosquitoes.

Return to the question,

What happens when we lose one of the organisms in an ecosystem? **(3.LS2.C; 3.LS4.D; 5.LS2.A; MS.LS2.A; MS.LS2.C; Cause & Effect: Mechanism & Explanation; Stability & Change)**

Here is an example of two species needing each other: In New Mexico, the state flower is the **yucca**. There is only one kind of insect that can pollinate the yucca flower; the **yucca moth**. Other insects may visit the flowers of a yucca, but only the yucca moth has the ability to pollinate them. If something were to happen to yucca moths and no more were alive, we would not have any more yucca plant seeds, and once the old yuccas die off, we would have no more yuccas. The yucca fruits are eaten by people and animals. Birds nest within the spiny leaves. Pueblo people have used this plant for generations to make string and rope for sandals, nets to catch food, and a soap from its roots. So, without one kind of insect, one kind of plant would be lost. The loss of that plant would affect many, many other organisms. It is for these reasons that we talk about threatened and endangered species. The yucca plant is a great example of a **mutually beneficial** interaction becoming so interdependent that the yucca depends on the yucca moth for survival. Neither would be able to survive without the other.

Can you think of other ***mutually beneficial*** *interactions among plants and animals? In what specific ways might plants and animals depend on each other? What happens if one partner in this mutually beneficial relationship is lost?* **(3.LS2.C; 3.LS4.D; MS.LS2.A; MS.LS2.C; Patterns; Cause & Effect: Mechanism & Explanation)**

Here is an example of a different type of habitat need: Along the Rio Grande, the large cottonwood trees sometimes have holes where a branch has died or a woodpecker has excavated a **nest cavity**. These cavities are used by many other birds for their nests. Woodpeckers can make their own holes, but other birds must find a hole already prepared. **Starlings**, birds introduced to America from Europe, have moved into the bosque and are very aggressive about claiming holes for nesting. They start early in the year before native birds nest or they push out the native birds and claim a hole for themselves. **Lucy's Warbler** (a SGCN) uses cavities for its nest in the bosque. Starlings can take over the cavity, preventing the warbler from finding a successful place to raise chicks. Another factor reducing the holes available for nests is that there are fewer large cottonwoods and more small trees like saltcedar and Russian olives. These trees are not native to North

America but, since their introduction by humans along the Rio Grande, they are the most common plants in some areas. They never get large enough for woodpeckers to make their nest holes. Without cavities in the trees, many species are not able to nest and raise young. **(3.LS2.C; 3.LS4.D; MS.LS2.A)**

- *How do introduced species affect native species?*
- *Are there ways humans can help cavity-nesting birds?* **(5.ESS3.C)**
- *What happens if some of these native species are no longer here?* **(5.LS2.A)**

Bullfrogs, introduced into New Mexico by humans as a food source (frog legs!), are large and can eat other frogs or tadpoles, such as the **Northern Leopard Frog**. Bullfrog predation is one of many factors affecting the success of this native frog, considered a SGCN. **(Cause & Effect: Mechanism & Explanation; Stability & Change)**

- *How do introduced bullfrogs affect native species?* **(5.LS2.A)**
- *How might humans help reduce bullfrog effects on other species?* **(5.ESS3.C)**

Do an additional round.

Swap animals and plants among students and include the Decomposer card this time.

- *How do decomposers fit in?*
- *If you didn't have decomposers, what would happen in the ecosystem?*
- *What is the role of decomposers in the web of life?* **(5.LS2.A; MS.LS2.B; Energy & Matter: Flows, Cycles & Conservation)**

Assessment:

- Return to the KWL charts. *What have students **Learned**? What additional questions do they have?*
- Design a bosque web of life based on what they know now.
- Have students draw "their" plant or animal along with other things it needs to survive, showing a web of life for that species.
- Do a group mural showing all the parts of the bosque ecosystem they have learned about. **(Systems & System Models; Energy & Matter: Flows, Cycles & Conservation; Developing & Using Models)**

Extensions:

- Have students identify non-living parts of the bosque ecosystem and the web of life they have created;
  - *What non-living factors are also necessary for these species to thrive?* (These might include soil type, temperature, fire, water amount and timing, etc.) **(3.LS2.C)**
- Have students highlight predators in the bosque:
  - *What role do predators play in this ecosystem?*
  - *What effect do predators have?* **(5.LS2.A; MS.LS2.A; Systems & System Models)**
- Think about competition between species:
  - *Are any species competing with each other?*
  - *What happens when species are competing for food, water, oxygen or*

other resources? For example, many species eat seeds on the ground. Some kinds of insects and mice are competing with birds such as the Spotted Towhee or Dark-eyed Junco for seeds on the ground. **(MS.LS2.A)**

- Research the plant or animal they have been in this activity, then write about it.
    - *What would a day or year in the life of this organism be?* **(Obtaining, Evaluating & Communicating Information)**
- Have your students think about human impacts in this bosque ecosystem. Students can research ideas they have about human impacts in the bosque.
    - *What sorts of human impacts would affect any of the species in the web of life they created? How would different species be impacted? How might humans mitigate these impacts?* Examples they might research: spraying to kill mosquitos, cutting down cottonwood trees, etc. **(5.ESS3.C; MS.ESS3.C; Cause & Effect: Mechanism & Explanation; Asking Questions & Defining Problems; Engaging in Argument from Evidence)**
    - *How would a change in the bosque plants or animals, such as those illustrated in this activity, affect humans? How does the biodiversity of our natural areas, such as the bosque, affect the lives of humans?* **(MS.LS4.D; Cause & Effect: Mechanism & Explanation)**
- Have students create short videos to share.

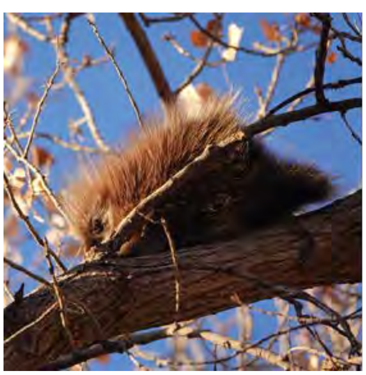
This activity could be paired with #46 "Energy in Bosque Ecosystems" to build on these concepts for 5th through middle school classes.

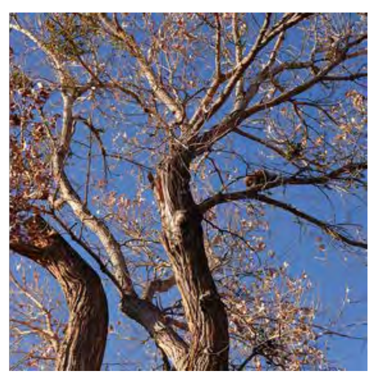
Resources:

Biota Information System of New Mexico (BISON-M) New Mexico Department of Game and Fish. https://bison-m.org

Kirkland, Jane. No Student Left Indoors—Creating a field guide to your Schoolyard. A Take a Walk Book. ISBN 13: 9780970975454

New Mexico Department of Game and Fish. 2016. State Wildlife Action Plan for New Mexico. New Mexico Department of Game and Fish, Santa Fe, New Mexico, USA.





Porcupette (young North American Porcupine) in the bosque west of Valle de Oro National Wildlife Refuge
photo by Laurel Ladwig

NGSS Connections to The Web: Disciplinary Core Ideas

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.*

Students can gain an understanding of the range of living things in a bosque environment in "The Web" activity, a basis to then consider various changes to the environment and consider the effects of those changes. Use nest cavity availability as an example. *How does the limited availability of cavities affect species dependent on them?*

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

This activity looks closely at a bosque habitat; food, water, shelter, space that an organism needs to survive. By doing "The Web" activity, students make connections in this habitat, then can consider what happens if one part is not there. Mosquitoes provide food for other animals. If humans remove the mosquito by spraying pesticides (illustrated by shaking the string) all other organisms will ultimately be affected.

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.*

This is a great activity to have students think about relationships in an ecosystem using the bosque as an example. They actively participate in thinking about food chains/food webs, specifically that some animals eat plants and others eat other animals. *What does each animal consume? What eats it?* Including the Decomposition card found in #46 "Energy in Bosque Ecosystems" activity will help understanding of decomposers in any ecosystem. The *Guide* has many examples of introduced species to illustrate their effects on the ecosystem. **Starlings** are an introduced species to North America. They are cavity nesters, using a hole in a tree that a woodpecker might have made. Starlings nest early in the season, occupying the cavities before others arrive, or they aggressively oust other birds from cavities they want. **Lucy's Warbler** is a SGCN in the bosque that uses cavities in trees to nest. Starlings can impact the nesting of this warbler.

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. Have students think about human impacts in this bosque ecosystem. Students can research ideas they have about human impacts in the bosque. *What sorts of human impacts would affect any of the species in the web of life they created?* Examples they might research include: spraying to kill mosquitoes, cutting down cottonwood trees, fires set by humans, habitat destruction, etc. *How are humans working to help protect the bosque and its species into the future? What engineering solutions are being implemented to protect the bosque into the future?*

MS.LS2.A Interdependent Relationships in Ecosystems
-Organisms and populations of organisms are dependent on their environmental interactions both with other living things and with nonliving factors.
-In any ecosystem, organisms and populations with similar requirements for food, water, oxygen or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction.
-Growth of organisms and population increases are limited by access to resources.
-Similarly, predatory interactions may reduce the number of organisms or eliminate whole populations of organisms. Mutually beneficial interactions, in contrast, may become so interdependent that each organism requires the other for survival. Although the species involved in these competitive, predatory, and mutually beneficial interactions vary across ecosystems, the patterns of interactions of organisms with their environments, both living and non-living, are shared.

This activity focuses on the interdependence of species in a bosque ecosystem by making connections in a web of life the students create. Try to get beyond "what eats what" in addressing this standard. Think of as many ways as you can in which one organism might need another: *Where will its home be? Does it need a place to perch to find food? Does it need the droppings of something to fertilize it?* Be creative in thinking of connections. Add non-living factors to achieve more of this standard (in Extensions). *Are any species competing with each other? What happens when species are competing for food, water, oxygen or other resources?* For example, many species eat seeds on the ground. Some kinds of insects are competing with birds such as the Spotted Towhee or Dark-eyed Junco for seeds on the ground. *What role do predators play in this ecosystem?* The yucca plant is a great example of mutually beneficial interactions becoming so interdependent that the yucca depends on the yucca moth for survival. Neither would be able to survive without the other. *Can you think of other mutually beneficial interactions among plants and animals?*

MS.LS2.B Cycles of Matter and Energy Transfer in Ecosystems *Food webs are models that demonstrate how matter and energy are transferred between producers, consumers, and decomposers as the three groups interact within an ecosystem. Transfers of matter into and out of the physical environment occur at every level. Decomposers recycle nutrients from dead plant or animal matter back to the soil in terrestrial environments or to the water in aquatic environments. The atoms that make up the organism in an ecosystem are cycled repeatedly between the living and non-living parts of the ecosystem.*
This activity is a good introduction to #46 "*Energy in Bosque Ecosystems"* activity. Students can be introduced to matter cycling in "*The Web"* to then puzzle through more complex ideas in the "*Energy in Bosque Ecosystems"* activity. One challenge is to tease apart the cycling of matter from the flow of energy in an ecosystem and the two activities together can give students the basis for this differentiation.

MS.LS2.C Ecosystem Dynamics, Functioning and Resilience

--Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations.

--Biodiversity describes the variety of species found in Earth's terrestrial and oceanic ecosystems. The completeness or integrity of an ecosystem's biodiversity is often used as a measure of its health.

"The Web" helps to illustrate the complexity of the biodiversity in a bosque ecosystem. Here, students can see the variety of connections between living organisms and then be challenged to see the effects of any changes. *If one aspect of the ecosystem is changed, are other organisms affected?* Use the example of the yucca and yucca moth. The loss of one will cause the loss of the other. Another example to illustrate the importance of a variety of species in an ecosystem is to consider the opposite; single crop farming. In Ireland in the 1800s, many farmers were growing only potatoes; a potato blight moved through, destroying the plants and resulting in a great famine. A diverse ecosystem will be more resilient in surviving over the long term; a single outbreak of a pest will not affect the majority of living organisms. *What happens when we lose one of the organisms in an ecosystem? Can you think of other mutually beneficial interactions among plants and animals? In what specific ways might plants and animals depend on each other? What happens if one partner in this mutually beneficial relationship is lost?*

MS.LS4.D Biodiversity and Humans *Changes in biodiversity can influence humans' resources, such as food, energy, and medicines, as well as ecosystem services that humans rely on—for example, water purification and recycling.*
Humans are in control of many aspects of the bosque through management of the river and introduction of non-native species to this area. Through research in the last decades, we can see many effects on bosque species. *How would a change in the bosque plants or animals, such as those illustrated in this activity, affect humans? How does biodiversity of our natural areas, such as the bosque, affect the lives of humans?*

MS.ESS3.C Human Impacts on Earth Systems

--Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things.

--Typically as human populations and per capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.

Human activities have altered many habitats along the Rio Grande and its floodplain. Have students think about human impacts in this bosque ecosystem. Students can research ideas they have about human impacts in the bosque. *What sorts of human impacts would affect any of the species in the web of life they created?* Examples they might research include: spraying to kill mosquitoes, cutting down cottonwood trees, fire, water flows, habitat destruction, etc. *How are humans working to help protect the bosque and its species into the future? What engineering solutions are being implemented to protect the bosque into the future?*

Woodhouse Toad
Photograph by Letitia Morris

Acknowledgments for Revisions 2022

Funding from New Mexico Department of Game and Fish, Share with Wildlife Program

Writing Group: Letitia Morris, Lisa Ellis, Karen Herzenberg, Molly Madden, Kelly White

Layout: Laurel Ladwig

Advisory Group: Selena Connealy, Heather MacCurdy, Deb Novak, Jennifer Owen-White

Teacher Fellows: Delfine Baca, Helen Haskell, Stephanie Kichler, Kim Orphal, Marnie Rehn, Heather Summers

Additional Reviewers: Charisa Bell, Cindy Chapman, Tamara Gaudet, Amy Grochowski, Michael Sanchez, Virginia Seamster, Shirley L. Pareo Srouji, Storm Ussery, Laura White

Thanks to the Friends of the Rio Grande Nature Center

20. Bosque Bugs Boogie

Description: Students search for arthropods on their school grounds and then participate in relay teams while mimicking bosque arthropods.

Objectives: Students will:

- discover some of the arthropods that live in their schoolyard (or backyard);
- learn about anatomical structures of arthropods that help in their survival; and
- learn some differences between insects, spiders, and other arthropods.

Materials:

- Cone or other target for bug turn-around spot
- Bug boxes, jars or other containers for temporary housing of arthropods
- Magnifying glasses
- Eight boxes or large paper grocery bags (fit over team members' heads)
- Optional: Bug eyes. Poke several holes in the bases of two paper cups or use commercially-purchased bug-eye toys (2 sets of 2); straws (2)
- Yarn or string (2 balls)

Phenomena: Arthropods are all around us, and they have a variety of shapes and sizes.

Lesson Questions:

- *What adaptations (structures) help arthropods survive?*
- *How do arthropod structures help them survive?*

20. Bosque Bugs Boogie

Grades: K-6

Time: 20 minutes outdoors (Bug Hunt), then 20 minutes for each round of relays (80 minutes total for relays)

Subjects: science

Terms: *antennae, appendages, arthropod, compound, exoskeleton, metamorphosis, segmented*

Optional: *chelicerae, elytra, gills, halteres, marsupium, nymph, ocelli, proboscis, spinnerets, tymbals, xylem*

New Mexico STEM Ready! / Next Generation Science Standards

NGSS DCIs

1.LS1.A Structure & Function
1.LS1.D Information Processing
3.LS2.D Social Interactions & Group Behavior
4.LS1.A Structure & Function
4.LS1.D Information Processing

NGSS CCCs

Patterns; Structure & Function

NGSS SEPs

Asking Questions & Defining Problems; Developing & Using Models; Planning & Carrying Out Investigations*; Analyzing & Interpreting Data*; Constructing Explanations & Designing Solutions; Engaging in Argument from Evidence*; Obtaining, Evaluating & Communicating Information*

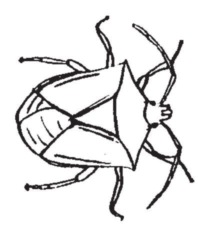
***indicates extension activity**

Background:

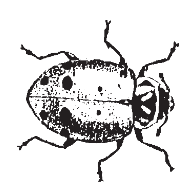
Did you know that most animals on earth are arthropods? These invertebrate (without backbones) animals have **exoskeletons**, **segmented** bodies, and paired, jointed **appendages**. They include insects, spiders, crustaceans, centipedes, and millipedes. They are highly successful at surviving in a wide variety of habitats. **Arthropods** (ARE-throw-pods) are everywhere, including in our backyards, school grounds, and city parks! They make excellent subjects for observation due to their abundance, small size, and ease of capture. All students will have some personal experience observing arthropods, so they will quickly get excited about this activity.

Estimates vary widely but there are nearly 7 million species of arthropods on Earth. Insects comprise the largest group of arthropods, by far. In fact, some scientists estimate that up to 80% of all animal species may be insects! In addition to the tremendous number of species, insects include the greatest biomass (amount by weight) of terrestrial animals on Earth. Simply put, there are many of types of insects and many, many individuals.

When we say "bugs", just what do we mean? The term "bug" is frequently used colloquially to refer to any "creepy crawly critter" (i.e., arthropods). To an entomologist (a scientist who studies insects), a "bug" is a member of the order Hemiptera, or true bugs. These include cicadas, aphids, leaf hoppers, bed bugs, and more. It's fine to use the term "bugs," but remember that officially, while all bugs are insects, not all insects are bugs!



stink bug - true bug



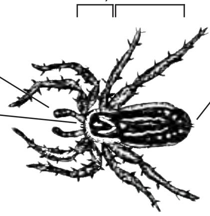
ladybird beetle
"ladybug" - beetle

Although one million species of insects have been named, estimates are that over 80% of existing insect species remain to be discovered and described. This is exciting news to share with students! There is a real need for more scientists all over the world who are trained to study insects before many species go extinct.

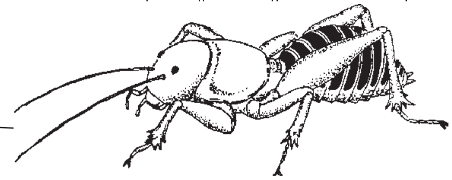
Arthropods, like all organisms, have a variety of internal and external structures that help the animal grow, survive, and reproduce. **(1.LS1.A; 4.LS1.A; Structure & Function)** For example, their jointed appendages are specialized in various ways for locomotion, feeding, and sensing the external world. Most insects have wings, specialized structures used for flight and other purposes. Arthropod mouthparts are specialized in ways that reflect the type of food each species eats. Some types of arthropods have structures that produce silk, which may be used to capture prey (spiders) or to protect larvae during **metamorphosis** (met-a-MOR-fuss-es) (moths and others). The variety of structural adaptations among arthropods is tremendous!

This activity focuses on some basic structural characteristics of arthropods, including their legs, wings, mouthparts, and other simple structures. Paying attention to these details helps develop observational skills and increase awareness of the amazing diversity of species of life on Earth. It's also a foundational step toward learning about animal classification.

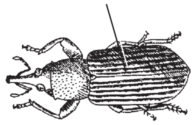
For more information on arthropods, see Appendix E.



spider
LAURA ROSENBERG

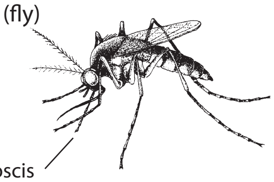


insect
Jerusalem
cricket
MIKE SANCHEZ



insect
weevil (beetle)
HELEN HASKELL

insect
mosquito (fly)



Pronunciation of Arthropod Terms:

antennae ann-TEN-ee	nymph NIM-f
chelicerae ki-LI-sir-ee	ocelli oh-SELL-eye
elytra EL-e-tra	proboscis pro-BOS-kes
halteres HALT-tears	spinnerets spin-er-ET
marsupium mar-SUE-pee-um	tymbals TIM-bulls
metamorphosis meta-MOR-fuss-es	xylem ZEYE-lem

Procedure:

Step 1: Bug Hunt

- Guide students through a discussion about arthropods. Use this to develop KWL charts. *What do the students **Know** about arthropods? What do they **Want** to know about arthropods?* You may return to these at the end of the activity and ask *What have they **Learned** about arthropods?*
  (Asking Questions & Defining Problems)

- Begin with a "Bug" Hunt around the school yard, or if learning remotely, in the child's yard, nearby park, or anywhere that is safe in the neighborhood. Arthropods really are everywhere, and close observation will quickly lead to many discoveries. You may collect individual arthropods for observation back in the classroom or at home using commercially-made bug boxes, glass jars with holes poked in the lids, or other similar containers. Encourage students to make their observations and then return the animal to where it was found (they can write the location on the container at the time of collection with a marker to help with remembering). It is a good habit to release the animals back where they were found while they are still healthy and able to survive (such as within 30 minutes). Minimize direct handling, both for the safety of the animal and of the student. Make sure students know about potentially dangerous arthropods, including centipedes, scorpions, black widow spiders, harvester ants, bees, and wasps. These are interesting and wonderful to observe but caution must be taken if capturing! At the collection site, record the habitat where each animal was found and any other interesting information (such as the presence of a web or burrow, feeding behaviors, if/how the animal was moving). Alternately, students may make all observations in the field rather than capturing the arthropods, or they may take photos to study in the classroom. Binoculars focused as close as possible may allow "spying" on arthropods without disturbing them.

- Back in the classroom or while outside ask the students to look closely at each arthropod. Record observations about each animal in their field notebooks, including the number of legs, the number of body parts (if possible; this can sometimes be difficult to determine), presence and number of wings, description of mouthparts, and any other interesting structures. Have the class develop a list of descriptive words about bugs to help with their writing.

- Next, focus the discussion on arthropod body parts. Animals have evolved behavioral and structural adaptations that enable them to grow, move around, find food, avoid predators, and find mates. Ask students, *What types of structures did you observe on the arthropods collected? What do you think each structure is used for?* **(1.LS1.A; 4.LS1.A)**

- Now consider arthropod legs. **Arthropods** belong to the Phylum Arthropoda, which is named from the Greek *arthros* (=jointed) and *poda* (=foot). All arthropods have jointed **appendages**. Arthropod legs come in many shapes and sizes and help the animals move in a variety of ways, including walking, climbing, and swimming. They also use legs or modified legs for feeding, sensing the environment, defending against predators, and capturing prey.

  Think about bugs you have seen. *Give an example of a type of bug leg and how it helps that bug.*

  Legs are also used by scientists to help in classifying arthropods. Noting the number of legs an arthropod has will tell you the type of arthropod it is. This is a practical application of patterns observed in nature **(Patterns)**.

  Insects – 3 pairs of legs

  Spiders, scorpions, ticks, mites, etc.– 4 pairs of legs

  Lobsters, shrimp, crabs – 5 pairs of legs

  Isopods – 7 pairs of legs

  Centipedes – one pair of legs per body segment

  Millipedes – two pairs of legs per body segment

Step 2: Relays - Round 1: Legs

- Determine the turn around target for the arthropod teams.

- Tell the students that they will be learning more about arthropods as they participate in relay laps while pretending to be arthropods.

- Divide the group into two teams. Ideally, each team should have at least ten members. Team members should line up single file, with teams side-by-side. Both teams will be the same arthropod in the same lap.

  Explain that each team will represent a particular arthropod using the appropriate number of students each time to form an animal group (see arthropod descriptions below). Focus first on the number of **legs**.

  How many legs does this arthropod have?

  How many students does it take to make this animal with this number of legs?

  Each team will need to determine how many legs the assigned arthropod has and how many students they will need to make an animal with that many legs. For example, if the arthropod is an **insect**, <u>three students will be needed</u> (three pairs of legs; use arms to hold on to waist or shoulders of the student in front and do not count them in the total number of appendages). For each lap, have a short discussion about the arthropod and then have students form groups to represent that animal. Groups must stay together, move in the manner outlined in the arthropod description (see below), and go out to and back from a designated target.

- Repeat the laps as many times as time and interest permit, but try to include at least one lap with each type of arthropod (insects, spiders, isopods, centipedes, millipedes). Again, the focus for this initial round is on legs. For younger students, you may want to stop here.

- Note that in these and other rounds of the relay, the students are acting as **models** of arthropods.

  How are models useful and what are their limitations?

  Models can help us learn, but they have limitations. For example, when three students are used to represent insects, we can note that insects have three body parts. However, this does not hold when four students represent a spider, as spiders have two body parts. This can be used for a discussion about the use of models. **(Developing & Using Models)**

  Tips for Relay: Choose 4 or 5 arthropods. Start with an insect—they have 3 pairs of legs/first three students; then spider with 4 pairs of legs/next four students; finish with either centipede or millipede that will use the entire line of students!

Relays - Round 2: Wings

- Next, repeat the relays for some of the arthropods but now include wings (see examples below). Start with a short discussion about insect wings. Think of examples of arthropods with wings at least part of their lives.

  What are the advantages of having wings?

  What functions do wings serve?

  You may want to add questions to students' KWL charts.

  Most, though not all, adult insects have wings. Wings allow insects to fly or glide, which increases the options available for finding food, mates, nesting locations, or resting places and has allowed insects to diversify into a wide variety of habitats. Insects are the only arthropods (and indeed the only invertebrates) that can fly. Wings serve other functions as well. The patterns on some wings (such as butterflies and moths) may provide camouflage, communicate warnings, or help to attract mates. Wings may aid in thermoregulation (butterflies and moths), auditory communication (crickets and katydids) or protection (beetles). **(1.LS1.A; 4.LS1.A)**

- Use the insect descriptions that include wings to set up groups for relays. Note that only insects have wings, so you will be working with three students per group for each of these animals. Insects typically have two pairs of wings. The front student in each group can flap both arms as wings. Since the students still need to hold on to each other, each of the middle and back students in the group can contribute one wing while holding on to the student in front with the other. All members of the Order Diptera (flies and their relatives) have only one pair of wings (Diptera is Greek for *di* [=two] and *ptera* [=wing]), so when representing mosquitos, only the front person in each group will flap their arms.

- Repeat the relay using examples that have wings (see below). Remember, these are all insects!

Relays - Round 3: Mouthparts (optional)

- Next, for older students, discuss the mouthparts of arthropods.

  How does the structure of the mouth influence the type of food it can eat?
  How does this affect survival?

  Arthropods don't have teeth! Mouth types provide information about the types of food arthropods eat. The diversity of arthropod species in part reflects the diversity of feeding habits. Sometimes, the different stages of development within a species have different mouth types, such as a caterpillar and a butterfly. There are a variety of mouth types, but here we will focus on those adapted for chewing, piercing, and sucking. Start this section with a short discussion of arthropod mouthparts, and add to KWL charts, if desired.

- Repeat the relays using information provided below and adding mouthparts to the student in front of the animal group. Students may simply pretend to suck, pierce or chew, or you may use tools such as a straw for sucking. This is a good time to include a brief discussion about the type of food the animal eats.**(1.LS1.A; 4.LS1.A)**

Relays - Round 4: Other Interesting Features (optional)

- **Arthropods have many fascinating structures!** A few of these other features are included with the information below. You can do additional rounds incorporating other structures. For example, when mimicking a garden spider, have the students move to a location where they must spool out yarn from their **spinnerets** (spin-er-ET) to create a simple web or wrap up a "prey" item in silk (use one ball of yarn or string for each team.)

- **Focus on sensory organs:** Arthropods use a variety of sensory organs to sample their environment, including sight, smell, taste, sound, touch, pressure, vibration, humidity, and temperature. **(1.LS1.D; 4.LS1.D)**

  How do arthropods use different types of sensory information to go about their daily activities?

  - Most arthropods have one of two types of eyes (and many have both): **compound** eyes and simple eyes (**ocelli**/ oh-SELL-eye). Large, bulging compound eyes may include up to thousands of individual lenses, providing an increased field of vision, good light and dark detection, and good motion detection. Ocelli contain only single lenses, used for detecting movement and changes in light. Most (but not all) adult insects have compound eyes, as well as two to three ocelli. Spiders usually have eight simple eyes (some have fewer), but they generally don't have very good eyesight. Spiders rely more on touch, vibration, and taste to find prey. Include eyes in your arthropod relays. Compound eyes can be made using two paper cups with many holes poked in the bottom or you can get commercially-made bug-eye toys with multi-faceted lenses.
  - **Antennae** (ann-TEN-ee) are important sensory organs for all adult arthropods except spiders and their kin (who have none). Antennae can be used to smell, taste, touch, and communicate. They come in many shapes and sizes! The first student in the arthropod group can wave their arms around like antennae, or have them close their eyes and feel their way along using "antennae" to determine where they are going. Do it safely!

- **Group living:** Being part of a group helps animals obtain food, defend themselves, and cope with changes. **(3.LS2.D)** Insects such as ants, bees, and termites live together in groups, sometimes including millions of individuals.

  What are advantages of living in a large group?

  Ants are completely dependent on group living, with individuals specialized into several different castes within a colony and each having a particular job to perform. Ants cannot live alone! Worker ants share in collecting food, protecting the nest from invaders, caring for young (produced by the single queen and a small number of males), keeping the nest clean, and so on. This extreme social behavior has allowed ants to become the most successful of all insect groups. See Harvester Ant below, for a group-living relay.

Assessments:

- Revisit the KWL charts. *What have students* ***Learned****? What else do they want to* ***Know****?* **(Asking Questions & Defining Problems)**

- Choose a bosque arthropod. Make a 3D-model, drawing, write a poem, or otherwise represent the arthropod showing the external structures that help this animal survive. Indicate the purpose of each of the structures, and provide an explanation for how each structure helps the animal survive. **(Developing & Using Models; Constructing Explanations)**

Modifications:

For remote learning, have students build arthropod models with pipe cleaners, sticks, Play-Doh clay or other material.

For safe-distancing when doing the relay, have students hold a rope, instead of each other.

Extensions:

- **Ant Investigations**

  Ants are everywhere and provide a convenient subject for investigations. Students can design their own projects to study ants either at home or in your schoolyard. Some possible questions to address:
  - *Where do ants build their nests?* Look for differences in locations of nest holes, such as in dirt, in grass, under trees, under pavement, under rocks. *What benefit do you think ants get from each location?*
  - *Does time of day affect ant activity?*
  - *Does temperature affect ant activity?*
  - *For harvester ants, where on the mound is the hole located*? Imagine the nest as a compass and record which direction the nest opening points. *Do you find any patterns?*
  - *Do ants have food preferences?* Test for differences by offering different foods, such as sugar, salt, citrus, seeds, berries, meat. Compare responses by different types of ants.
  - Follow a worker ant to see where she goes and what she does. **(Asking Questions & Defining Problems; Planning & Carrying Out Investigations; Analyzing & Interpreting Data)**

- Compare the structure and function of arthropod bodies to those of vertebrate animals. *What is it about arthropods that have made them so successful and much more diverse than vertebrates?*
    - Compare the exoskeleton of arthropods to the vertebrate skeleton. *What are the advantages and disadvantages of each?*
    - Arthropod **exoskeletons** are made up of chitin, while vertebrate skeletons are made of bone. Compare these materials. *What are the advantages and disadvantages of each?*
    - Compare the material and structure of insect wings with those of bird wings. *What are the advantages and disadvantages of each?* **(Patterns; Structure & Function; Engaging in Argument from Evidence; Obtaining, Evaluating & Communicating Information)**

NGSS Connections to Bosque Bugs Boogie - Disciplinary Core Ideas

1.LS1.A Structure and Function *All organisms have external parts. Different animals use their body parts in different ways to see, hear, grasp objects, protect themselves, move from place to place, and seek, find, and take in food, water and air.*

Arthropods have a variety of structures that allow them to survive in various habitats, including the bosque and river. Focus on particular structural adaptations of arthropods, including legs, wings, eyes, antennae, spinnerets or other structures. Consider how these adaptations help the animal grow, get food and water, survive predators or competitors, reproduce or endure seasonal changes.
What features does each species have that allow it to live in the bosque or river?
How do these structures increase the animal's chance of surviving?

1.LS1.D Information Processing *Animals have different body parts that capture and convey different kinds of information needed for growth and survival. Animals respond to these inputs with behaviors that help them survive.*

Arthropods have specialized sensory organs designed to sample a variety of types of information in their environment. Eyes and antennae provide good examples of sensory organs in arthropods.
In what ways do sensory organs of arthropods differ from those of vertebrate animals?
How does sensory input affect an animal's ability to survive? How might an animal's behavior be affected by certain types of sensory inputs?

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.*

Several types of insects are specialized to live in groups, including ants, honey bees and termites. Harvester ants provide a good example of this in the bosque. Individuals in these groups are specialized to perform certain behaviors that benefit the entire colony; this specialization requires that the individuals remain part of the group to survive.
In what ways does living in a group help harvester ants?
How do individual members contribute to survival of the entire colony?

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.*

Arthropods have a variety of structures that allow them to survive in various habitats, including the bosque and river. Focus on particular structural adaptations of arthropods, including legs, wings, eyes, antennae, spinnerets or other structures. Consider how these adaptations help the animal grow, get food and water, survive predators or competitors, reproduce or endure seasonal changes.
What features does each species have that allow it to live in the bosque or river?
How do these structures increase the animal's chance of surviving?

4.LS1.D Information Processing *Different sense receptors are specialized for particular kinds of information, which may then be processed by an animal's brain. Animals are able to use their perceptions and memories to guide their actions.*

Arthropods have specialized sensory organs designed to sample a variety of types of information in their environment. Eyes and antennae provide good examples of sensory organs in arthropods.
In what ways do sensory organs of arthropods differ from those of vertebrate animals?
How does sensory input affect an animal's ability to survive? How might an animal's behavior be affected by certain types of sensory inputs?

Summary of Arthropods for Relays

Name	Arthropod Class	# Body Segments	# Legs [# students = # legs / 2]	# Wings (larvae/adult)	Mouth Parts	Eyes	# Antenna
Tarantula	Arachnida	2	8	0	piercing	8 simple	0
Garden Spider	Arachnida	2	8	0	piercing	8 simple	0
Jumping Spider	Arachnida	2	8	0	piercing	8 simple	0
Centipedes	Chilopoda	many	many (one pair per body segment)	0	piercing	many simple	2
Millipedes	Diplopoda	many	many (two pairs per body segment)	0	chewing	simple (poorly developed)	2
Isopods	Isopoda	many	14	0	chewing	2 compound	4
Mayfly	Insecta	3	6	0/4	chewing; none in adult	2 compound 3 simple	2
Field Cricket	Insecta	3	6	4	chewing	2 compound 3 simple	2
Plains Cicada	Insecta	3	6	4	piercing & sucking	2 compound 3 simple	2
Darkling Beetle	Insecta	3	6	4	chewing	2 compound	2
Harvester Ant	Insecta	3	6	0/4	chewing	2 compound 3 simple	2
Monarch Butterfly	Insecta	3	6	0/4	larvae chewing; adult sucking	larvae 12 simple; adults 2 compound, 2 simple	2
Mosquito	Insecta	3	6	0/2	piercing & sucking	2 compound 3 simple	2

The Bosque Education Guide

Tarantula

Description: Eight legs requires four students. Eight eyes; the male is near-sighted, so the students must wear a box or bag over their heads so it is hard for them to see; back students keep their hands on the hips or shoulders of the student in front of them. Males live eight to ten years in burrows; when a male is sexually mature, it goes looking for a mate. Females generally never leave their burrows.

Wings: None

Mouthparts: Piercing (**chelicerae**/ ki-LI-sir-ee). Tarantulas inject a venom that kills their prey, but they cannot chew it. Instead, they inject digestive enzymes that break down the prey, and then the tarantula slurps up the liquid meal. Prey includes other arthropods and small vertebrates. The tarantula's stomach works like a pump to suck up the liquified prey, so they can eat animals much bigger than themselves.

Other Interesting Features: Tarantulas have **spinnerets** (spin-er-ET) but they don't spin webs to catch their prey. Instead, they use their silk to line their burrows and protect their eggs. Tarantulas also have spigots on their feet that produce silk; this silk is used to help prevent the spider from slipping on steep and slippery surfaces.

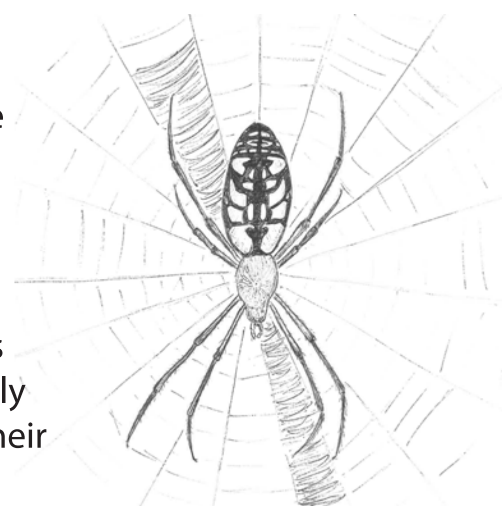
Garden Spider

Description: Eight legs requires four students. Eight eyes, all students keep their heads up, stand side to side with arms on waist or shoulder of student next to them and walk to move.

Wings: None

Mouthparts: Piercing (**chelicerae**/ ki-LI-sir-ee). Produce venom, with which they kill insects that are trapped in their web.

Other Interesting Features: Garden spiders have **spinnerets** (spin-er-ET) that produce silk, with which they produce large orb webs used to capture prey. Webs have a characteristic zigzag pattern; the spider is usually sitting near the center of the web. The spiders wrap their prey in silk before biting and feeding on them.



MIKE SANCHEZ

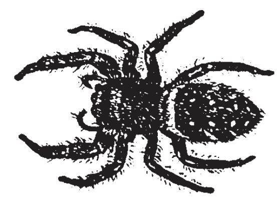
Jumping Spider

Description: Eight legs requires four students. Eight eyes (very good vision); have students line up side-by-side with arms linked across shoulders. Students must jump forward to move.

Wings: None

Mouthparts: Piercing. Jumping spiders are active predators. They do not hunt in webs but rather actively seek out prey on the ground and in vegetation. They produce venom from fang-like structures (**chelicerae**/ ki-LI-sir-ee).

Other Interesting Features: Although they don't spin webs, jumping spiders do have **spinnerets** (spin-er-ET) that produce silk, which they use as a safety line to stabilize their large jumps. They also produce silk "pup tents" for shelter.



jumping spider

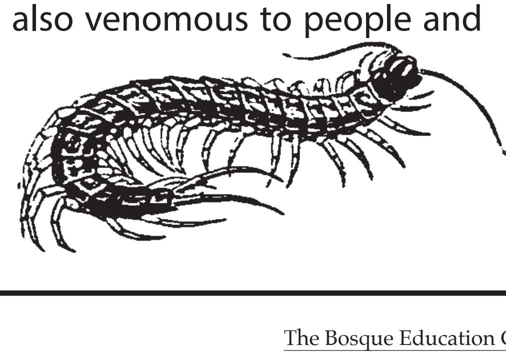
Centipede

Description: Many legs; all team members participate. Since the centipede is flat with one pair of legs per body segment, students will bend over at the waist, the back students holding onto the waist of the student in front of them. The legs are extended to the sides of the centipede, so students run with their legs spread wide apart. Centipedes are flat, which enables them to easily crawl underneath rocks and logs. Two clusters of simple eyes. One pair of long **antennae** (ann-TEN-ee).

Wings: None

Mouthparts: Piercing. Centipedes are predators that eat small insects and other arthropods.

Other Interesting Features: The forelegs are modified into fangs that deliver venom with which they paralyze their prey. This poison is also venomous to people and can cause a painful bite. The appendages on the rear of the centipede are modified for sensory functions but can also pinch.



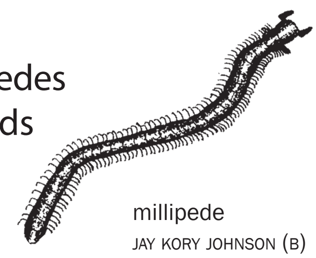
Millipede

Description: Many legs; all team members participate. Millipedes have poor eyesight from poorly-developed eyes. They tap the ground with **antennae** (ann-TEN-ee) (one pair) when they move, so the front student uses arms to feel in front while other students keep heads down. A millipede is round and has two pairs of legs per body segment; the back students keep their hands on the shoulders of the student in front of them and hunch their shoulders. All students must shuffle their feet.

Wings: None

Mouthparts: Chewing. Millipedes feed on decaying leaves and other dead plant material.

Other Interesting Features: When handled or disturbed, millipedes may coil up and release a foul-smelling, toxic fluid from glands located on the tops of the legs. This is used for protection.



millipede
JAY KORY JOHNSON (B)

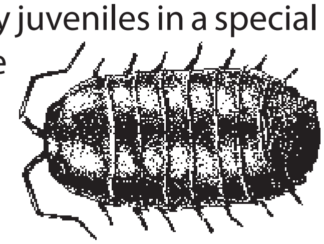
Isopod (Pill bugs)

Description: Fourteen legs requires seven students. Two compound eyes mean that the back six students must keep their heads down while the front student may use imitation compound eyes (two paper cups with many holes poked in the end or commercially-produced bug eye toys). Back students keep hands on hips or shoulders of students in front of them. Two pairs of jointed **antennae** (ann-TEN-ee).

Wings: None

Mouthparts: Chewing. Isopods eat decaying wood and leaves. Note that isopods were introduced to this continent long ago with dirt that was used to stabilize sailing vessels but was then removed to make room for cargo space on return trips. They are now the major consumers of dead plant material in the bosque.

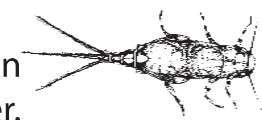
Other Interesting Features: Female isopods carry their eggs and tiny juveniles in a special pouch called a **marsupium** (mar-SUE-pee-um). Isopods breathe through **gills** and so require moist environments (but cannot survive being submerged in water). One species can roll up!



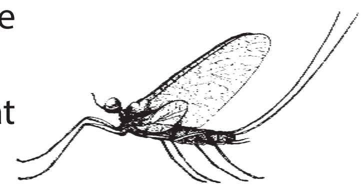
Mayfly

Description: Six legs requires three students. Two compound eyes mean that the back two students must keep their heads down while the front student may use imitation compound eyes (two paper cups with many holes poked in the end or commercially-produced bug eye toys). Back two students keep hands on hips or shoulders of students in front of them. One pair of short, bristle-like **antennae** (ann-TEN-ee).

Wings: Immature mayflies (called **nymphs**/ NIM-fs) are aquatic and have no wings. Adults have one or two pairs of wings that are held upright over the back (they can't fold their wings down like some insects do).



Mouthparts: Nymphs have chewing mouthparts. Most feed on diatoms, algae, and other plants and organic detritus under water. Adult mayflies live only a few hours to a few days. They have vestigial mouthparts and do not feed.



Other Interesting Features: Mayflies have three long tails that provide stability during flight.

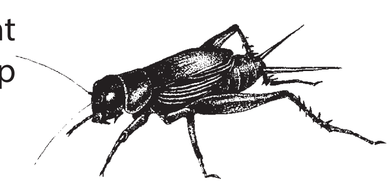
Field Cricket

Description: Six legs requires three students. Two compound eyes mean that the back two students must keep their heads down while the front student may use imitation compound eyes (two paper cups with many holes poked in the end or commercially-produced bug eye toys). Back two students keep hands on hips or shoulders of students in front of them. One pair of long **antennae** (ann-TEN-ee). All of the group must jump.

Wings: Field crickets have two pairs of functional wings, though they spend more time walking or jumping than flying. In addition to flight, wings function in communication. Male crickets rub their wings together to chirp to attract mates. One wing has a scraper and one wing has a file and when these are rubbed together, they make the chirping sound. (Note that some types of crickets, such as camel crickets, do not have wings.)

Mouthparts: Crickets have chewing mouthparts. They eat dead leaves and insects and, before the arrival of isopods, may have been the major consumer of fallen cottonwood leaves in the bosque.

Other Interesting Features: Cricket ears are located on their front legs! Enlarged hind legs are adapted for jumping. They can jump about 30 times their body length to escape predators.

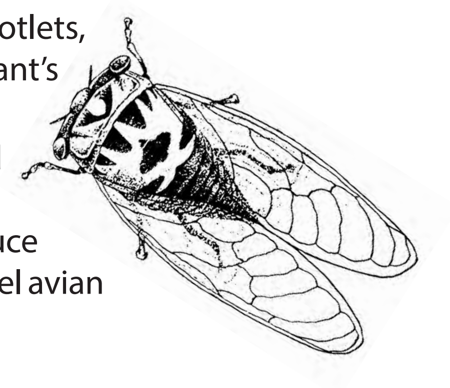


Plains Cicada

Description: Six legs requires three students. Two compound eyes mean that the back two students must keep their heads down while the front student may use imitation compound eyes (two paper cups with many holes poked in the end or commercially-produced bug eye toys). Back two students keep hands on hips or shoulders of students in front of them. One pair of short **antennae** (ann-TEN-ee).

Wings: Adult cicadas have two pairs of functional wings but they are somewhat clumsy fliers. Note that wingless **nymphs** (NIM-fs) live and grow underground for 3 to 5 years, emerging in their final nymph stage to climb up into a tree or bush, shed their skin, and become a winged adult.

Mouthparts: Cicadas use a straw-like beak that can pierce rootlets, roots, and stems of trees, allowing the cicada to suck up the plant's **xylem** (ZEYE-lem) (sap-containing transport tubes).



Other Interesting Features: Cicadas make a loud buzzing sound by vibrating a pair of sound organs, called **tymbals** (TIM-bulls), located on the sides of the abdomen. Males of each species produce a characteristic song. The song is used to attract mates and to repel avian predators. Some individuals will emerge every year.

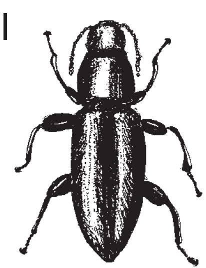
Darkling Beetle

Description: Six legs requires three students. Two compound eyes (adults) mean that the back two students must keep their heads down while the front student may use imitation compound eyes (two paper cups with many holes poked in the end or commercially-produced bug-eye toys). One pair of long **antennae** (ann-TEN-ee).

Wings: Adults have two pairs of wings. The front pair of wings in all beetles form a thick, leathery wing cover (called the **elytra**/ EL-e-tra) to protect the delicate flight wings folded underneath. Many species of darkling beetles do not fly.

Mouthparts: Chewing. Darkling beetles feed on plant material (adults feed on plants and seeds above the surface while larvae feed on plant material underground).

Other Interesting Features: When adults are disturbed, they do a headstand; to deter predators, they may spray a noxious liquid from a gland located in the abdomen.



darkling beetle
CAROLYN BARR (B)

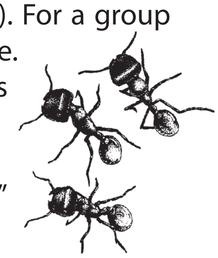
Harvester Ant

Description: Six legs requires three students. Two compound eyes mean that the back two students keep their heads down while the front student may use imitation compound eyes (two paper cups with many holes poked in the end or commercially-produced bug eye toys); back students keep their hands on the hips or shoulders of the student in front of them.

Wings: Worker ants do not have wings. During the breeding season, winged males and females form mating swarms; after mating, the females shed their wings and establish new nesting sites while the males soon die. Those with wings have two functional pairs.

Mouthparts: Chewing. Harvester ants eat seeds that they collect and bring into the nest. They chew the seeds into a mash that is stored underground for future consumption. They will also occasionally eat other small arthropods, including isopods. Note that harvester ants will bite viciously to defend their colony, and they can also inject venom by stinging.

Other Interesting Features: Harvester ants live in large colonies in burrows that can be nine feet (3 meters) deep or deeper. The workers go out to forage following scent trails left by scout ants. They communicate information about food availability with each other by touching **antennae** (ann-TEN-ee). For a group relay, each student represents one ant and the whole team will follow along in single file. Note that while the "ants" in the relay have only two legs, the real ants have six! Use arms as antennae and feel along the path to find your way or to communicate with colony-mates (brief and gentle touches only!) To be really authentic, bend arms at elbows as ants have "elbowed" antennae. Follow the path to a seed source, where each ant collects one "seed" to carry back to the colony. **(3.LS2.D)**



Monarch Butterfly

Description: Larva (caterpillar) has three pairs of true legs (near the front end) and five pairs of prolegs (leg-like appendages near the hind end); requires eight students. The caterpillar pushes and pulls its body along—inch-worm style; students have hands on hips of the team member in front of them. The first three students (the real legs) move forward as far as possible without the back team members moving. Then the front students stop while the remainder of the team moves as close to the front students as possible. Once the back person stops, front members can move again. Caterpillars have six pairs of simple eyes (12 **ocelli**/ oh-SELL-eye); adult butterflies have two compound eyes and two ocelli. One pair of **antennae** (ann-TEN-ee) (short in caterpillars, long and clubbed in butterflies).

Wings: Adult butterflies have four wings, two forewings and two hindwings, that are held together in flight to function as one wing; each wing is covered with scales and hairs. The coloration of monarch wings provides a warning to predators that they are toxic. Note that the species is known for its long migration between Canada and the U.S. to Mexico; much of the western U.S. population moves to the California coast for the winter. Larvae (caterpillars) do not have wings.

Mouthparts: Larvae: Chewing; Adults: Sucking (**proboscis**/ pro-BOS-kes). Larvae feed on milkweed leaves; adults feed on nectar from a variety of flowers.

Other Interesting Features: Monarch caterpillars have internal adaptations that allow them to eat toxic milkweed leaves without becoming sick themselves, but both adults and caterpillars can pass along the toxin to animals that eat them. Because those predators would then become sick, the colorful orange and black pattern of the monarch's wings serves as a warning that they are poisonous and thus acts as a deterrent.

Mosquito

Description: Six legs requires three students. Two compound eyes mean that the back two students keep their heads down; back students keep their hands on the hips or shoulders of the student in front of them. One pair of long **antennae** (ann-TEN-ee) (feathery in males, plain in females).

Wings: Mosquito larvae are aquatic and do not have wings. Adult mosquitoes (like all flies) have one pair of wings. Mosquito wings are long and thin and the mosquito flaps them very quickly; a structure on the wings rubs together to make a buzzing sound, which is used to attract mates.

Mouthparts: Piercing and sucking. All adult mosquitoes have a **proboscis** (pro-BOS-kes) to eat nectar or plant sap. The female's proboscis can also pierce skin and allows it to feed on blood, which it needs to produce eggs. Larvae eat algae and other aquatic microorganisms.

Other Interesting Features: A structure on the antennae is used to detect vibrations of sound; this is basically the mosquito's ear. Female mosquitoes also have structures that can detect carbon dioxide and other organic compounds released by animals; they use this to find a suitable host. Vestigial hindwings form a pair of club-like **halteres** (HALT-tears), which help stabilize the mosquito during flight.

21. Bosque Survey

Description: Students develop a true/false survey of their knowledge of the bosque, then administer the survey to others and analyze the response data.

Objectives: Students will:

- review what they have learned about the bosque;
- learn what others know about the bosque;
- educate participants in the survey and their community about the bosque; and
- learn about surveying techniques by conducting a simple survey, collecting data, organizing and displaying data and analyzing survey results.

Materials:

- Copies of the Bosque Survey tabulation sheet
- Pencils
- Calculator

Phenomenon: People who live near the bosque often don't know much about it.

Lesson Question:

- *What do other people know about the bosque?*

21. Bosque Survey

Grades: 5–8

Time: two class periods plus administration of survey

Subjects: science, math

Terms: *Variable depending on the direction the questions take*

New Mexico STEM Ready! / Next Generation Science Standards

NGSS DCIs

Variable depending on the direction the questions take and focus if it is a summary activity

NGSS CCCs

Variable depending on the direction the questions take

NGSS SEPs

Asking Questions; Analyzing & Interpreting Data; Using Mathematics & Computational Thinking; Obtaining, Evaluating & Communicating Information*

Mathematics: Statistics & Probability

6.SP Develop understanding of statistical variability; Summarize & describe distributions

7.SP Use random sampling to draw inferences about a population; Draw informal comparative inferences about two populations.

(* indicates extension activity)

Background:

This activity can serve as an assessment following the River of Change unit (Chapter 4) or it can be developed to follow up any of the individual activities. Once your students have completed the River of Change activities, they should be bursting with new knowledge that they are ready to share. The survey format included here allows students to use their knowledge to develop questions about the bosque that they will ask of family, friends, neighbors, etc. In an optional extension, students follow up on the most often missed questions by presenting information about the bosque to their community.

This is a good opportunity to tie in mathematics and cover some Statistics and Probability Standards.

Procedure:

- After completing the River of Change unit, ask students what they have learned about the bosque (and river). *What was the most interesting thing you learned? The most unusual or unexpected thing? Has your opinion about the bosque changed with your new knowledge?* Then ask what they would like other people to know about the bosque. *What is the most important information you want to share?* Revisit your KWL charts. *What interesting questions arose during your studies?*
- Students develop a list of questions to survey what people know about the bosque. As a class, choose ten statements that will test peoples' knowledge. See ***Tips for Developing Statements*** for helpful suggestions. Give students time to propose True/False statements and discuss as a class which will be the most interesting to include.

  Another option is for students to write bosque information on slips of paper (un-signed) and put them in a hat. The teacher selects some to turn into true/false survey statements. This is a way to model creating survey statements. **(Asking Questions)**

- A sample survey is included. If time is short and you want to focus on the mathematical exercise, you may use the included survey instead of having students develop their own questions.

Tips for Developing Statements for Survey Questions

- Use KWL charts created while doing River of Change and other activities to determine what students learned and what else they want to know.
- Remember that the point of these statements is not to stump people or make a very difficult survey but rather to encourage the sharing of knowledge about the bosque.
- Use True/False statements. These are the easiest to tabulate.
- Include ten questions in your survey to simplify statistical analyses.

- Practice interviewing in class either in pairs or demonstrating with the teacher in front of the class with one or two students. The students practice how to tell respondents the correct information in appropriate ways. The practice respondent should get a few things wrong on purpose. Students should be encouraged to talk with the respondent about what they learned in their study of the bosque, not just repeat the statement to the respondent and tell them they got it right or wrong.
- Review percentages and averaging with your class. *If someone has eight of ten correct--what percent is correct?* Have the students calculate percentages for each practice survey.
- Review the draft survey to determine whether questions should be revised. Make any changes needed. For example, a question might be too technical for a general audience or phrased in a confusing way.
- Have students predict how they think the respondents will do. *What questions will they get right? Which will be hard for the respondents?* Have them write their thoughts down. They can even discuss percentages here--*what percent of people are likely to get this answer correct?* They can base these predictions on what they as a group knew before their unit on the bosque, so not just on wild guesses. After the survey, compare their predictions with the actual results.
- Prepare for conducting the survey. Go over the instructions on the survey. Discuss how many people will be questioned by each student. Your goal is to survey 100 people. (A class of 20 will survey five people each.) Students might take questions home to ask family, friends and neighbors, or your class might survey other classes at school. Official surveyors will start by stating the purpose of the survey, how the data will be shared, and that answers will be confidential.
- After each survey, students should go over the correct answers with those they have surveyed and tell them the percentage answered correctly. In teaching about the bosque in this way, students solidify their own knowledge.

- Students will return with all of their surveys completed, correct answers recorded, and percentage correct answers calculated.
- Now students combine their results with the rest of the class. Go through each question and record the total number of correct answers of all the people surveyed. If you surveyed 100 people, this number represents the percentage of correct answers for each question.
    - count the total correct (out of ten questions) for each person and average the sums across 100 people = average score for the whole survey.
    - for each question, count the total correct across the 100 people and that is your percentage correct for that question. Do that for each of the 10 questions.
    - how did these answers compare to their expectations regarding correct responses before conducting the survey
- Students display the data in some way, using a graph, chart, etc. Data can be organized in dot plots, histograms or box plots. Give measures of center and describe the overall patterns and any striking deviation from that pattern.
- Find the mean and median and discuss by looking at the organization of the data which was the best to help them answer their question. **(6.SP; Analyzing & Interpreting Data; Using Mathematics & Computational Thinking)**
- Students answer the analysis questions.

  Analysis Questions:
    - *Which questions were answered correctly by most participants?*
    - *Which question(s) were answered incorrectly by the most participants?*
    - Make a general statement about the level of knowledge and understanding of the bosque among the people surveyed.
    - Discuss the validity of their sample. Use this sample to draw inferences about a population. *Do you think these results will be true for the general public? Why or why not?* Have students average the number of correct responses across their five respondents and compare to the average of the full group (100 people). *Does their sample fit with the results of the overall average? Does the overall average give a result that makes sense based on the individual results?* **(7.SP)**

Assessment:

Writing questions about the bosque and weighing the most interesting or important ideas to share in a survey will show their learning of bosque concepts as they conclude a unit about the bosque. Surveying others and calculating the results will further their skills of using statistics. Finally they must evaluate the results through answering the Analysis Questions. **(Analyzing & Interpreting Data)**

Extensions:

- Write a news article about your findings.
- Take the questions that were most often answered incorrectly and design something to teach that information. This could be done using posters, videos, leaflets, etc.—an "ad campaign." Present this to family, friends, neighbors or other classes. Consider different ways to share the information, such as a presentation to the PTA or to other classes, a table at a community event, postings on social media, etc. **(Obtaining, Evaluating & Communicating Information)**
- Follow this exercise with Activity #38 "River Stories" to collect oral histories about the Rio Grande.

Mathematics Standards:
Statistics & Probability

6.SP *Develop understanding of statistical variability; Summarize & describe distributions*

7.SP *Use random sampling to draw inferences about a population; Draw informal comparative inferences about two populations.*

Say's Phoebe at Valle de Oro National Wildlife Refuge
Photograph by Laurel Ladwig

Bosque Survey

1	2	3	4	5	Is this statement True or False?
(5 people surveyed)					
					1.
					2.
					3.
					4.
					5.
					6.
					7.
					8.
					9.
					10.
					Number of correct answers
					Percentage correct (multiply by 10)

Student's name ____

Instructions

- Read the statements to five participants and record their True (T) or False (F) answers in Columns 1 through 5.
- Have correct answers on the next page. Go over the correct answers with each participant after they have answered the survey questions. Use your own words and knowledge of the bosque.
- Sum the total correct (out of ten statements) for each person and tell them their score.
- Back in class, average the number correct across 100 people = average score for the whole survey.
- For each statement, count the total correct across 100 people and that is your average for that statement. Do that for each of the 10 questions.

Bosque Survey

1	2	3	4	5	Is this statement True or False?
(5 people surveyed)					
					1. A Rio Grande cottonwood lives about 300 years.
					2. Cottonwood seeds can germinate anywhere so most survive to start new trees.
					3. Saltcedar and elm trees have always been a part of the Rio Grande bosque.
					4. Rio Grande cottonwood trees get all the moisture they need from rain.
					5. We don't have to be concerned about the bosque. It will always be the way it is now.
					6. The cottonwood has been the most important tree in the bosque for thousands of years.
					7. The bosque and river provide important habitat for animals that are threatened or endangered or at risk of becoming so.
					8. Historically, annual floods provided wet ground that cottonwood seeds needed to grow and develop.
					9. Cottonwood trees have either female or male flowers but not both on the same tree.
					10. Land managers are able to create conditions artificially that allow cottonwoods and other native plants to germinate and grow.
					Number of correct answers
					Percentage correct (multiply by 10)

Student's name ____

Instructions

- Read the statements to five participants and record their True (T) or False (F) answers in Columns 1 through 5.
- Have correct answers on the next page. Go over the correct answers with each participant after they have answered the survey questions. Use your own words and knowledge of the bosque.
- Sum the total correct (out of ten statements) for each person and tell them their score.
- Back in class, average the number correct across 100 people = average score for the whole survey.
- For each statement, count the total correct across 100 people and that is your average for that statement. Do that for each of the 10 questions.

Answers to Bosque Survey

1. False: Cottonwood trees are like people—not many grow to be more than 100 years old. Cottonwoods are not long-lived trees.
2. False: Cottonwood seeds need sunlight, a clear space and soil that stays wet until the seedling roots reach the water table. Very few seeds germinate. Even fewer find the conditions needed to develop into trees.
3. False: Saltcedar and elm trees came to the bosque in the 1930s. Russian olive was also introduced about the same time.
4. False: Large trees like cottonwoods need much more than the 10 inches (25 cm) of rain that make our area a desert. We often get even less than that. Cottonwoods tap the water table/groundwater for their needs.
5. False: The bosque has always been changing following natural cycles. But today's changes are not cyclical. Instead, they represent a progression from one type of habitat to another. Without responsible management, the bosque may not survive as a cottonwood forest.
6. True: The Rio Grande cottonwood has been evolving with the river for more than a million years. Cottonwood leaves that look like our modern cottonwood trees are preserved as fossils near the Albuquerque airport in ash from the Jemez volcano eruption 1.2 million years ago.
7. True: Threatened, endangered or rare species that use the bosque, river or floodplain include the Northern Leopard Frog, Bald Eagle, Yellow-billed Cuckoo, Southwestern Willow Flycatcher, Rio Grande Silvery Minnow, and New Mexico Jumping Mouse. These species are also classified as Species of Greatest Conservation Need (SGCN) by the New Mexico Department of Game and Fish.
8. True: Annual floods kept the soil wet long enough for this to happen. Because the river is now controlled by levees and dams, it no longer floods unless managers allow it.
9. True: Cottonwoods with male flowers release pollen in the spring. It floats in the air to the trees with female flowers that later produce the cottony seeds.
10. True: Some strategies that land managers use include creating artificial floods, clearing sandbars, constructing channels that allow water to move into the forest, and planting cottonwood poles.

There are many ways people can help restore the forest.

22. *Mapping Species Richness*

Description: Students first map their campus (or backyard, park, etc.) to determine where animals occur. Then, they color a map that shows how many species of birds live in different areas of New Mexico, and by overlaying maps containing other information, they learn what factors are important to avian distribution.

Objectives: Students will learn that in the arid Southwest, the highest number of kinds of birds (species richness) live along rivers (i.e., places with water).

Materials:

- Mapping Species Richness map for each student to color
- Mapping Species Richness data sheet for each student
- Colored pencils
- Copies of the following maps: New Mexico Rivers and 1,000-foot (300 meters) Elevation Contours (included in this activity). These could be on clear acetate, to overlay on the students' maps and/or show on an overhead, or students can hold paper copies up to a window to compare. If you have access to other maps, such as the New Mexico highway map, NM vegetation maps, NM geology maps, etc., they may be used as reference.

Phenomenon: Birds are found in different habitats in New Mexico.

Lesson Question:

- *Why does a bird live in one place and not another?*

22. *Mapping Species Richness*

Grades: 6–12

Time: one class period for mapping outside (Part 1); two class periods, plus homework, for mapping species richness (Part 2)

Subjects: science, math extension

Terms: *biodiversity, community, extirpated, flyway, riparian, species, species diversity, species richness, vagrants*

New Mexico STEM Ready! / Next Generation Science Standards

NGSS DCIs

MS.LS2.A Interdependent Relationships in Ecosystems
MS.LS2.C Ecosystems Dynamics, Functioning & Resilience
MS.ESS3.D Global Climate Change
HS.LS2.A Interdependent Relationships in Ecosystems
HS.LS2.C Ecosystems Dynamics, Functioning & Resilience
HS.LS4.D Biodiversity & Humans
HS.ESS3.D Global Climate Change

NGSS CCCs

Patterns; Cause & Effect: Mechanism & Explanation

NGSS SEPs

Asking Questions & Defining Problems; Developing & Using Models; Analyzing & Interpreting Data; Constructing Explanations & Designing Solutions; Engaging in Argument from Evidence; Obtaining, Evaluating & Communicating Information*
(* indicates extension activity)

Terms

Biodiversity: biological diversity. In considering the ecological condition of an area, biological diversity refers to the variety of organisms present, looking at all levels of classification and genetic variability, and the variety of ecosystems in which the organisms occur.

Community: an association of interacting species inhabiting an area. An example would be a pond community with all the animals and plants that depend on the pond and live in or near the pond.

Flyway: the path taken by birds during their annual migrations. Many birds will take the same route each year, following a river or mountain crest as landmarks for their journey.

Riparian: relating to, living near, or located on the bank of a natural fresh watercourse (stream, river) or waterbody (pond, lake).

Species: a group of organisms, such as one type of bird, that is able to interbreed and produce fertile offspring.

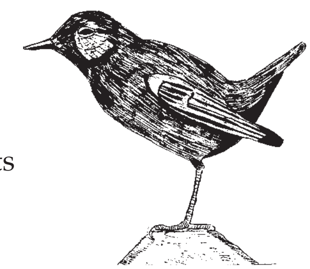
Species diversity: a combination of the number of species in a community (species richness) and the relative abundance of the different species.

Species richness: the number of species in a community or location. This contrasts with the abundance or numbers of individuals. Species richness is simply a measure of the number of types of organisms present without regard to the number of individuals. Thus, a site with 10 different types of birds present has a higher richness than a site with five species present, even if the latter site has 100 individuals and the first site has 50 individuals. Caution: Be aware that identical richness numbers don't mean that the same species of birds occur at different sites with the same species richness value.

Background:

Scientists in many fields use color to look for patterns, particularly in combination with maps of various types of information; these serve as models of real-life conditions. For example, geologists create colorful maps of where different types of rocks are found and then study the patterns that appear in order to understand the geology of an area. The maps represent 2-dimensional models of the distribution of rock types. In this activity, students illustrate the number of **species** of birds found in different areas of the state by coloring a map in a "color-by-number" style. These maps serve as models of species richness across the state. Students compare their species richness maps to maps with other types of information, such as vegetation type, geology, aquatic features or elevation, to look for patterns in species distribution and suggest possible causation.

When scientists and resource managers prioritize which natural places on Earth to preserve, one factor they are particularly interested in is the number of species of organisms present at a given site. Biological diversity, or **biodiversity**, includes both species richness and the relative abundance of each species. In general, sites with more species are said to have higher biodiversity. Although sites with fewer species can also be ecologically quite important, sites that support more species are especially valuable and these are typically targeted for conservation. It is essential to understand what ecological factors promote this higher diversity in order to protect the species living there. Habitats that have been greatly reduced in extent and are now rare are also important conservation priorities, since they often support species found nowhere else.


American Dipper

Animals live throughout New Mexico, but if you look specifically where those animals live, far more kinds are found along streams, rivers and lakes than in drier uplands. In New Mexico, less than 1% of the state supports **riparian** habitat, but large numbers of vertebrate animal species depend on those riparian areas for at least part of their lives.[1] For example, deer will wander far and wide, but they must come to water to drink regularly. This is particularly noticeable with species of birds. More species of birds are found in riparian habitats than in all other vegetation types combined.

This activity is designed to demonstrate the importance of the bosque ecosystem to birds in New Mexico. A 1984 study of animal life along the Middle Rio Grande Valley reported 277 species of birds sighted during two years; this was over 60% of the total number of birds known from the state at that time.[2] Data compiled in 2021 include 367 species of birds found in riparian habitat along the Middle Rio Grande, which includes **vagrants** (species outside their normal range) and rare sightings.[3] The total number of species reported in the state in 2021 stands at 546,[4] also including vagrants and rare sightings, meaning about 67% of bird species have been recorded in riparian habitat. The larger number of bird species recorded for the state reflects, in part, an increased sample effort as more people are observing birds and submitting their species lists as part of citizen science projects. Although some species, such as the Whooping Crane, have been **extirpated** (gone extinct locally, though they still exist elsewhere) from the state, other species, such as the Eurasian Collared Dove, have extended their ranges into the state. Rare sightings may reflect one or two individuals that were out of their normal range.

The persistence of riparian habitat as the planet warms is uncertain, which poses a great threat to species of birds and other animals that depend on it. Climate change increases the chance for worsening drought in the Southwest; droughts here are expected to get more frequent, more intense and last longer. Sites that support riparian vegetation now may not do so in future. This will severely limit habitat vital to these riparian-dependent species. As your students work through this activity, have them think about the effects of decreasing water in this arid state, and what that will mean for riparian vegetation and riparian-dependent birds.

Note that the data used in this activity are from around the year 2000, when 324 birds were routinely seen somewhere in the state. Birds that appear irregularly or infrequently were not considered as they are not a substantial part of the ecological community. The numbers in the chart are extrapolated from actual records compiled by the U.S. Geological Survey's GAP Analysis Project and simplified in some cases to easily demonstrate ideas to students. One or two sites are used to illustrate larger regions. For each site we have grouped the total numbers of bird species that can be seen in the area if observed regularly throughout the year. Some birds may live there in the winter and migrate in the spring; some may only be seen in the spring or fall migration; some will nest in that area; still others will live in one spot all year long.

Procedure:

- Mapping the Campus (or your backyard, park or other nearby area)
  - Introduce the activity with the questions: *Where have you seen animals in New Mexico?* and *Where do you think most animals occur in the state?*
  - Ask students why they think animals occur in the places that they do.
  - Now bring the discussion closer to home: *Where do animals occur on our campus? (or in your backyard or neighborhood?) Why do you think they occur where they do?* Let's map the campus to figure this out!
  - Make a map of your campus (or backyard, park, or part of your neighborhood). This can be as simple or complex as you choose, but at minimum indicate areas with pavement, buildings, water sources, grass, bushes, trees, or other types of vegetation as appropriate. Make note of any bird feeders or other sources of food.
    - Using this map as a base, go out and look for animals and then mark where they are observed. You can choose to focus on birds only (as the latter part of this activity does) or all animals, including arthropods.
    - *Looking at the map showing where you observed animals, do you see any patterns of where animals occur? What factors do you think affect the distribution of different species? What do animals need to survive?* **(Patterns; Cause & Effect: Mechanism & Prediction)**
- Mapping Bird Species Richness
  - Now, focus on birds with the question: *Where do birds in New Mexico live?* Start with students' experiences: *Where have you seen birds?* Think about different places the students have been while out doing different activities, such as walking, hiking, camping, picnicking, hunting, riding bikes, or even driving around town. *What types of birds have you seen?*
  - Then consider: *What factors affect bird distribution? Why do you see some kinds of birds in some places but not in other places?* Note that different species have different requirements.

- Have students brainstorm possible factors affecting distribution (for example, presence of tall trees, soil type, elevation, water) and develop hypotheses based on their favorite suggested answers; write them down. Think about testing these hypotheses: *How would we find out?* Record expectations, predictions, interests, and connections. **(Asking Questions & Defining Problems)**
- Next, present the following scenario: Biologists have studied birds all over the state and recorded the numbers of birds and the numbers of species of birds, in many different habitats and areas in the state. Your task is to use these data on the numbers of species of birds to determine which areas in the state are most important to birds. To do this, you will make a map of species richness. Start by looking at the locations and number of species found at each location and then color that area of the state according to the color assigned to that number.

Belted Kingfisher

  - Give the students the Mapping Species Richness data sheet and map showing statewide locations and the number of bird species found at each location.
  - Instruct students to match locations on the map to the number of birds found.
  - Students assign a color to each of the categories in the map key. We recommend that a bright red or orange be used for the highest number of species. Official maps go through the color spectrum with blue for the fewest species, grading to green, yellow, orange and then red as the highest category (i.e., the largest number of species).
  - Have students color the Mapping Species Richness map. Remind students that numbers for the regions are extrapolated from data from one or a couple of sites within each region. Therefore, students may find more than one site within a given region that they are coloring.
  - When the students have finished their maps, have them compare their species richness maps to maps of other types of information (geology, vegetation, soil type, etc.), based on initial predictions about what factors influence bird distribution. Let students consider a variety of possible factors. [Information regarding online maps is in the *Extension* section below.]
  - Then go back to the original question: *Where do most species of birds in New Mexico live? What other questions could we ask from these data?*
  - Assist them in comparing their species richness maps to maps with other information and ask: *How does the species richness of birds relate to this?*
  - For example, overlay the elevation contour map (provided). Ask students if there is a relationship between elevation and

numbers of birds (NOTE: There is not a strong relationship with elevation; this map is provided as a possible factor for the sake of comparison.) *What other ideas do students have?*

- Finally, overlay the Rivers of New Mexico map (provided). *Is there a relationship between the location of rivers and species richness?* Students should see a strong correlation between the location of rivers and the number of species of birds in an area. **(Developing & Using Models; Analyzing & Interpreting Data)**

Discussion (after maps are colored)

The main theme: *Where is the highest diversity of bird species?*

Overlay the Rivers of New Mexico map. Students should be able to see that the rivers/riparian areas have a very high species richness, therefore many different kinds of birds.

Where are the rivers on this map?

Is there a relationship between rivers and the bird species richness? Why? What is different about river systems compared to areas of the state where there are no rivers? **(Patterns; Cause & Effect: Mechanism & Prediction)**

There is more water, but what else is there? When you look at the bosque compared to the dry areas adjacent to the floodplain, how is the floodplain different? There are tall trees, a greater density of plants, and larger plants. With taller plants, for example, there are more nest sites for birds (canopy and cavity nesters). More insects live on the large trees and over water, so insect eaters find more food there; more insect eaters mean more predators to eat them, etc.

What other factors influence bird distribution?

What are the most important things to determine why birds occur where they are?

What are the things all animals need to survive?

Where are you safe from predators?

Animals need habitat: food, water, shelter, and space in the proper arrangement. Water is extremely important in the dry Southwest. Water is a limiting resource. Many species occur only where there is a reliable water source. This is particularly important during the breeding season.

How does access to water affect the distribution of birds in New Mexico? **(MS.LS2.A; HS.LS2.A)**

Look at the species richness map. *Which sites contain the fewest species? Can we look at other maps to see why so few species live there?* Some types of areas have very few species; these include lava flow areas such as El Malpais and desert areas such as Chaco Canyon in the Great Basin Desert.

Look at Sites 2 and 4, which appear to have the same number of species. *Do they have the same species?* Look at the habitats. These are very different environments; even though they may have similar numbers of bird species, the actual types of birds will be very different.

Where do we find sandhill cranes in New Mexico? Why are they there? Why are they in this corridor? Talk about migration **flyways**: many birds will follow rivers in their migration. Others, such as hawks, fly along mountain ridges as landmarks for their journey. Sandhill Cranes fly from the northern U.S. and Canada to winter in a warmer place, including New Mexico. They are abundant in the Middle Rio Grande Valley in winter because there is food, water and safe places to roost. (See the "Crane Migration" activity for additional information.)

What does the number of species in an area say about the health of the local environment? In general, a large number of species indicates a healthy habitat and a high biodiversity. But be careful: even though there are few bird species at El Malpais, the plants and animals that live there have important adaptations that allow them to survive in the unique lava flow environment. Also, introduced / exotic species will increase the species richness but not necessarily the biological diversity / health of the environment. **(MS.LS2.C; HS.LS4.D)**

What happens when a habitat changes? New Mexico is experiencing increased drought due in part to climate change. Conditions are likely to get hotter and drier, with warmer winters and less snowpack and ultimately decreased stream flows. *How will this affect the bird species that rely on riparian habitats?* Riparian habitat in New Mexico supports several Species of Greatest Conservation Need (SGCN), including the Bald Eagle, Yellow-billed Cuckoo, Lucy's Warbler and Southwestern Willow Flycatcher. *What will happen to these species as New Mexico gets drier? In what ways can humans mitigate these changing conditions?* **(MS.LS2.C; MS.ESS3.D; HS.LS2.C; HS.LS4.D; HS.ESS3.D)**

Assessment:

- Students can write a statement of conclusion regarding their original hypothesis and indicating the results of testing that hypothesis. If the available data did not address their hypothesis, have them state this. Then have them summarize the results of doing this activity.
- Write a Claim, Evidence, Reasoning statement that:
  - Explains the importance of riparian habitat for birds in New Mexico.

Bushtit collecting nesting material in an ABQ Backyard Refuge
Photograph by Laurel Ladwig

- ◦ Explains the effect that climate change will have on bird populations that depend on riparian habitats.
- ◦ Suggests solutions to mitigate climate change effects on riparian systems and bird populations.
  (Constructing Explanations & Designing Solutions; Engaging in Argument from Evidence)

Suggested Adaptations:

- You are a "birder" (you watch birds) and want to see wintering geese.
  - Where would you go? What about this area makes it a good place to see geese?
  - Why would you go to rivers to find ducks?
- Many birds migrate, but not all; compare birds that migrate and those that do not. *Why do some migrate and some don't?*

Extensions:

Students can research individual species of birds, including where they occur and which habitats they live in. *What kinds of birds live in particular areas on their maps?* There is a list of birds of the Middle Rio Grande in Appendix F. Share these species accounts with the class or with families.

- Have students choose a species of bird that lives in the bosque to research.
  - Write about the habitats that species needs, the food it eats, the type of nest it uses, etc.
  - *Why does it live in the bosque? Are there other places it could/does live?*
  - *Does it migrate?*
  - *Where does it spend the summer and winter?* **(Obtaining, Evaluating & Communicating Information)**

Math Extensions:

This activity uses data from around 2000; at that time at least 324 bird species were routinely recorded in New Mexico and were included in the total species numbers in this activity. That value excluded vagrant species and rare sightings. The current species list for New Mexico contains 546 species, which includes vagrants and rare birds. eBird (https://ebird.org) is an online, citizen science project that collects bird species checklists from people visiting a variety of locations and makes the data available to all through their website. This provides updated species richness data for these locations that can be used to supplement this activity.

- Explain to students that the data provided on the Mapping Species Richness Data Sheet for this activity was gathered during limited field surveys, so it represents a relatively small sample size. Then explain that eBird is a citizen science project that gathers bird checklists from anyone who wants to submit them, based on their observations in the field. The sampling effort is much greater for the eBird data.
- Look up the following five locations on the Mapping Species Richness

Data Sheet: Bosque del Apache NWR, Bitter Lakes Refuge, Las Vegas NWR, Rio Grande Nature Center, Rattlesnake Springs Preserve. Use the species richness values provided on the data sheet to calculate the percent of statewide species found at each site (using 324 as the total species richness of New Mexico).

- Next, have students use eBird to find updated species richness estimates for the same five sites. Note that some sites, such as Bosque del Apache, have more than one entry. Try to find the main location (with the most species) for each site. Calculate the percent of statewide species using the updated values from eBird and a total state species richness of 546. They will find that the percentages increase for each of the locations.
- Now interpret the data and encourage students to discuss what the values mean:
  - *What do the percentage values represent?*
  - *Why do the values change between the two sampling periods?*
  - *Why might eBird species lists include more species?* (Note that you can see sample efforts for each site in the number of checklists used.)
  - These sites include some of the highest bird species richness values for the state. *What is it about these sites that make them so attractive for birds?*

  (Patterns; Analyzing & Interpreting Data)

Mapping Extensions:

- Use iNaturalist in Step 1 to document animals on the school grounds. Students can record animal identifications and map their locations.
- Using Google Earth, locate your school yard or other area you mapped. *How does your habitat map compare to the aerial photos?* Next, locate one or more of the sites included on the species richness data sheet. *Can you identify different vegetation types? How useful are the aerial photos for representing the habitat at a given site? Can you use them to estimate the extent of each type of vegetation or habitat at a given location?*

  (Developing & Using Models)

Other map sites to try:

New Mexico Department of Game and Fish Environmental Review Tool; look for "Wetland and Riparian Areas" map layer: https://nmert.org/content/map

USGS Map; look at specific species of vertebrates and the habitats where they are found: https://maps.usgs.gov/gap-species/

EPA EnviroAtlas; has interactive maps, student lessons, and ways to look up riparian areas: https://www.epa.gov/enviroatlas

References:

1 Knopf, P.J., R.R, Johnson, T. Rich, and R.C. Szaro. 1988. Conservation of riparian ecosystems in the United States. Wilson Bulletin 100:272-284.

2 Hink, V.C., and R.D. Ohmart. 1984. Middle Rio Grande biological survey. Report submitted to U.S. Army Corps of Engineers, Albuquerque, NM.

3 T. Fetz, personal communication, November 11, 2021

4 Williams, S.O. III. 2021. Checklist of New Mexico Bird Species. New Mexico Ornithological Society, Albuquerque, NM.

NGSS Connections to Mapping Species Richness – Disciplinary Core Ideas

MS.LS2.A Interdependent Relationships in Ecosystems

-Organisms and populations of organisms, are dependent on their environmental interactions both with other living things and with nonliving factors.

-In any ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction.

-Growth of organisms and population increases are limited by access to resources.

In the arid Southwest, water is a limiting resource. Many species occur only where there is a reliable water source. This is particularly important during the breeding season.

How does access to water affect the distribution of birds in New Mexico? What other factors influence bird distribution?

MS.LS2.C Ecosystem Dynamics, Functioning and Resilience

-Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations.

-Biodiversity describes the variety of species found in Earth's terrestrial and oceanic ecosystems. The completeness or integrity of an ecosystem's biodiversity is often used as a measure of its health.

The Southwest is becoming hotter and drier due in part to climate change. Warmer winters will mean decreased snow packs and decreased stream flows. This will affect the plant and bird species in riparian habitats, including possibly changing the groups of species that are able to survive in these habitats. *What happens to ecosystems when the environment changes? What happens to the species of animals living there? What impact will this have on riparian habitats, and on animals that depend on these habitats?*

MS.ESS3.D Global Climate Change *Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and the other kinds of knowledge, such as understanding of human behavior, and on applying that knowledge wisely in decisions and activities.*

Riparian habitats are especially vulnerable to drought, which is increasing in the Southwest due to climate change. This activity shows that many bird species are particularly dependent on riparian ecosystems for their survival. *How will increasing temperatures and drought affect birds dependent on riparian habitat?*

HS. LS2.A Interdependent Relationships in Ecosystems *Ecosystems have carrying capacities, which are limits to the number of organisms and populations they can support. These limits result from such factors as the availability of living and non-living resources and from such challenges as predation, competition, and disease.*

In the arid Southwest, water is a limiting resource. Many species occur only where there is a reliable water source. This is particularly important during the breeding season. *How does access to water affect the distribution of birds in New Mexico? What other factors influence bird distribution?*

HS.LS2.C Ecosystem Dynamics, Functioning and Resilience

-A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in condition or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability.

-Moreover, anthropogenic changes (induced by human activity) in the environment—including habitat destruction, pollution, introduction of invasive species, over exploitation, and climate change—can disrupt an ecosystem and threaten the survival of some species.

The Southwest is becoming hotter and drier due in part to climate change. Warmer winters will mean decreased snowpack and decreased stream flows. This will affect the plant and bird species in riparian habitats, including possibly changing the groups of species that are able to survive in these habitats. *What happens to ecosystems when the environment changes? What happens to the species of animals living there? What impact will this have on riparian habitats, and on animals that depend on these habitats?*

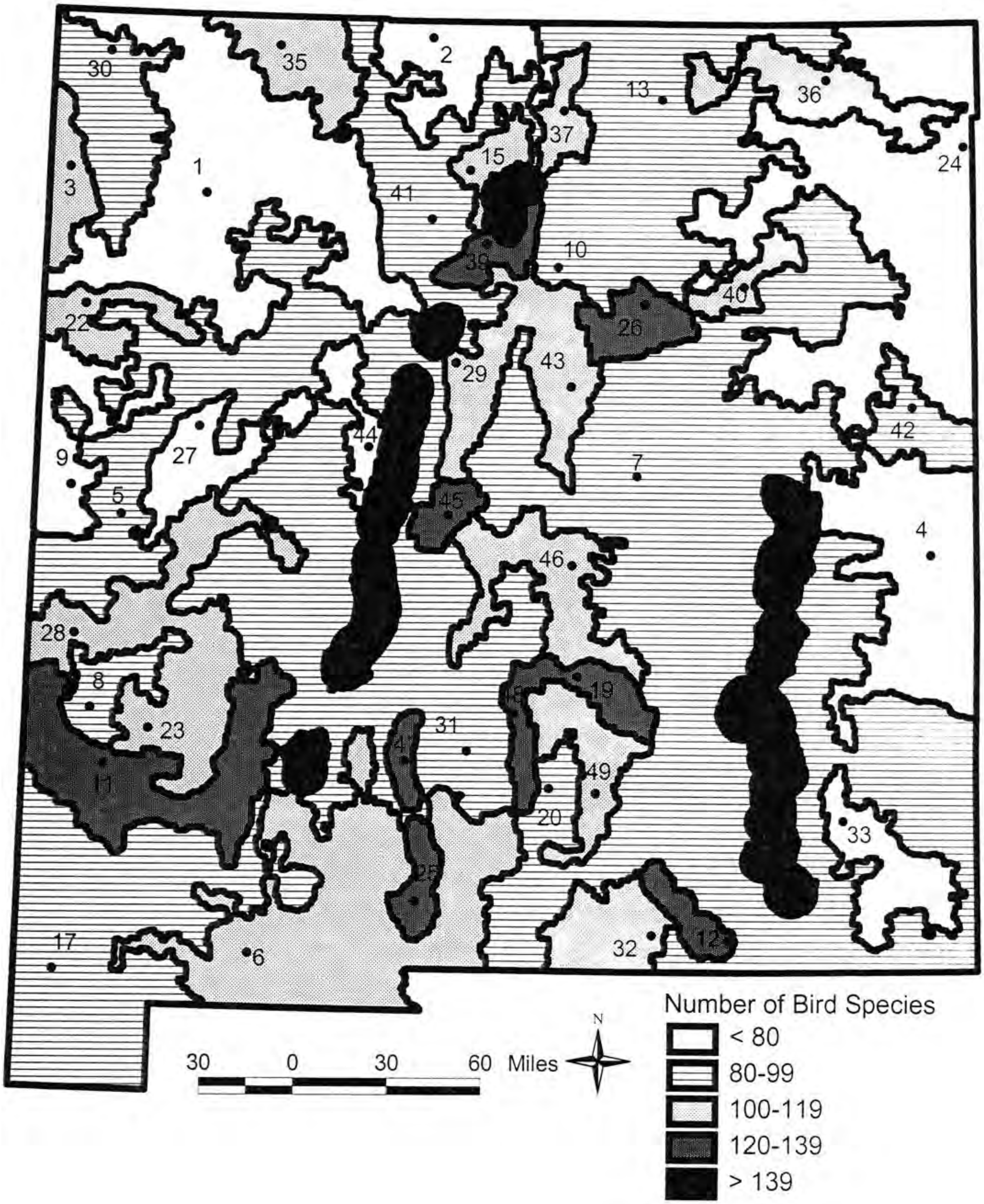
HS.LS4.D Biodiversity and Humans *Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus, sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value.*

The Southwest is becoming hotter and drier. Decreased stream flows, lowered groundwater levels and increased wildfires all impact riparian vegetation, as does direct habitat destruction by humans. *How will decreases in the extent of riparian vegetation impact bird populations? How might humans mitigate these changes?*

HS.ESS3.D Global Climate Change *Though the magnitude of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts.*

Riparian habitats are especially vulnerable to drought, which is increasing in the Southwest due to climate change. This activity shows that many bird species are particularly dependent on riparian ecosystems for their survival. *How can humans decrease impacts of climate change on riparian systems? In what ways will those improvements benefit local bird populations? What will happen to these species as New Mexico gets drier? In what ways can humans mitigate these changing conditions?*

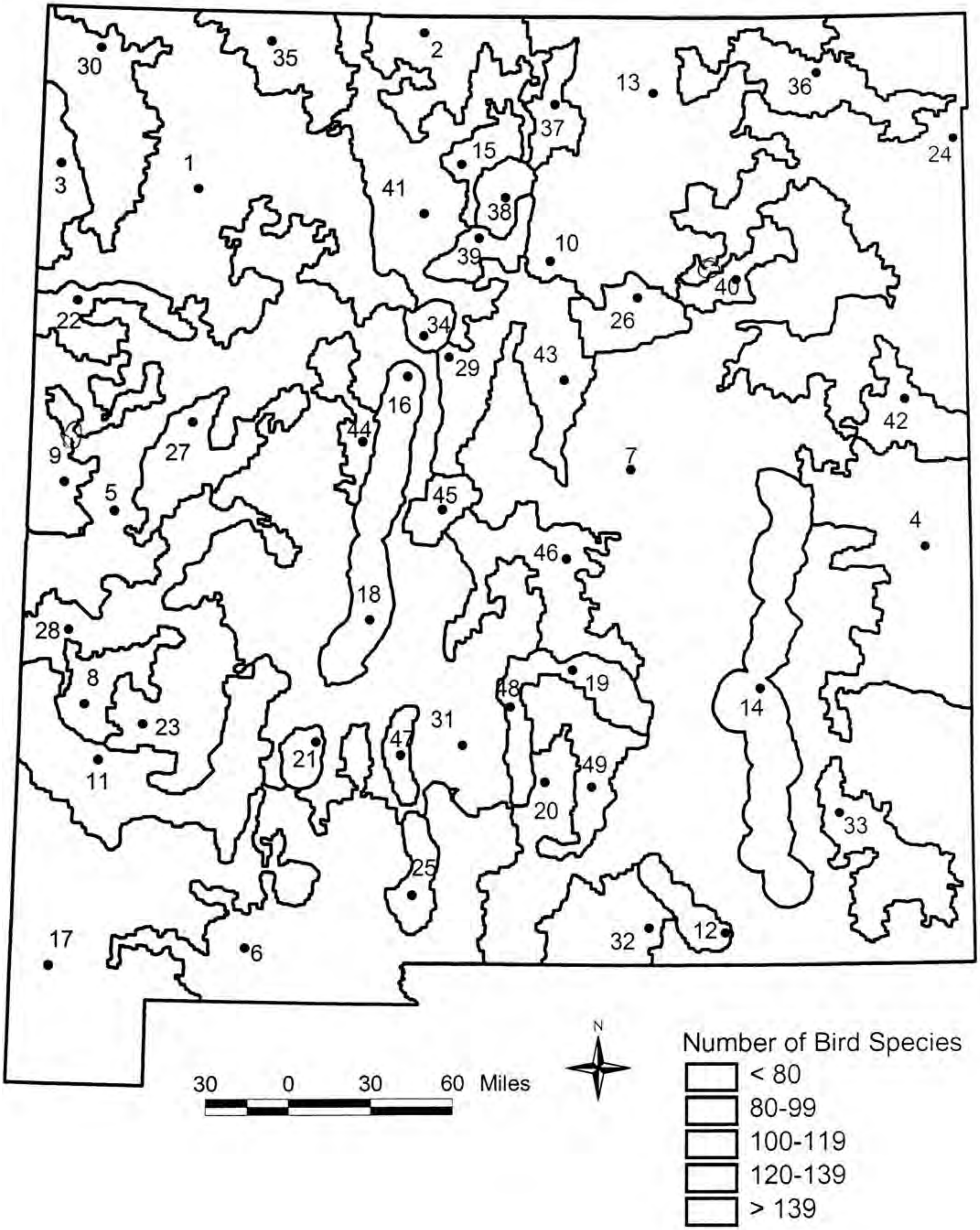
Teacher Key: Bird Richness



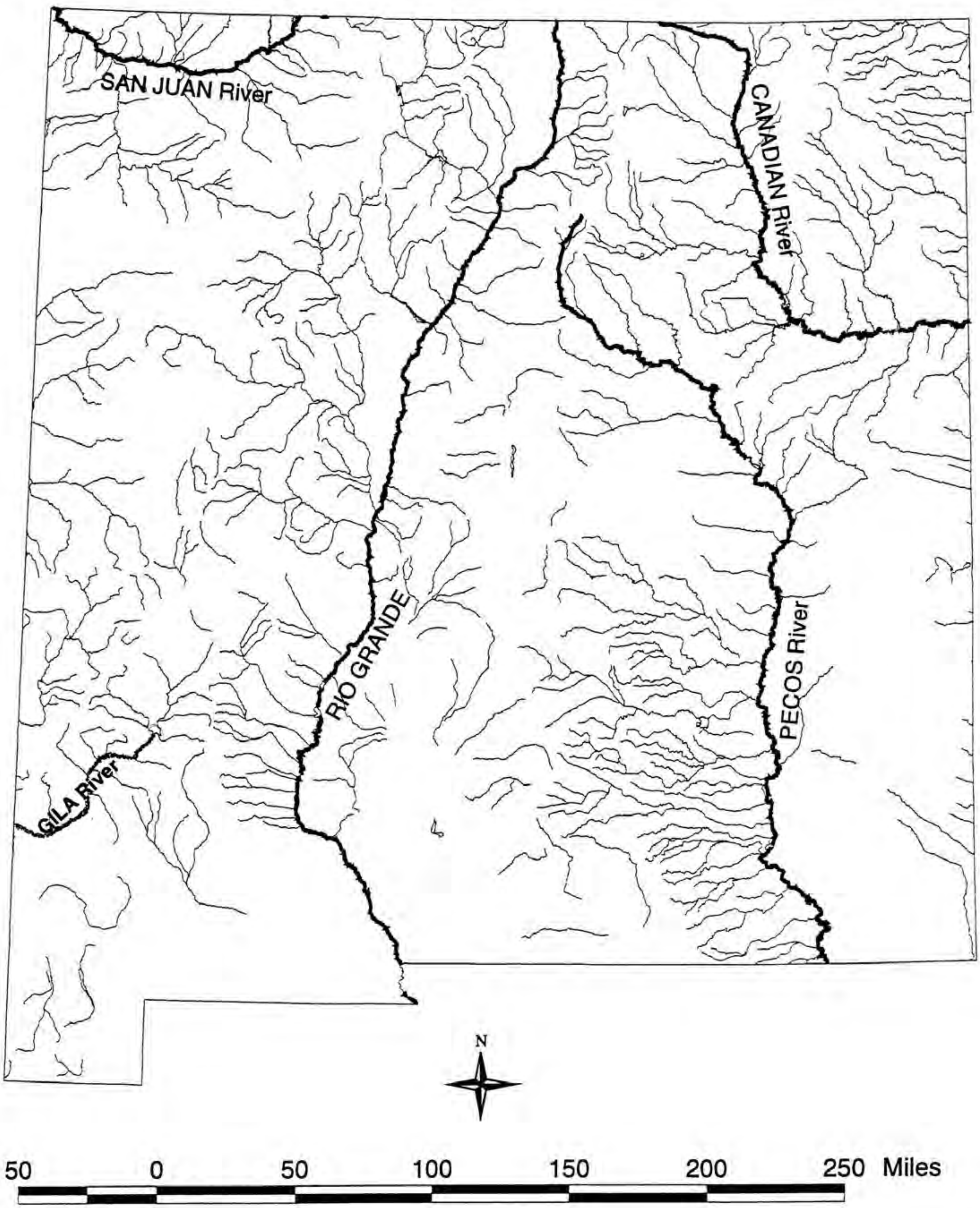
Mapping Species Richness Data Sheet

Site #	Name	Species Richness
1	San Juan Basin	43
2	Chama	65
3	Chuska Mountains	113
4	Portales	53
5	Quemado	94
6	Rock Hound State Park	103
7	Vaughn	92
8	Whitewater Baldy	86
9	Zuni Salt Lake	55
10	Randall Davey Audubon Center	94
11	Gila Riparian Preserve	124
12	Rattlesnake Springs Preserve	121
13	Philmont Scout Ranch	82
14	Bitter Lakes Refuge	159
15	Abiquiu	115
16	Rio Grande Nature Center State Park	143
17	Animas	98
18	Bosque del Apache National Wildlife Refuge	169
19	Capitan	133
20	Cloudcroft	82
21	Elephant Butte Reservoir	145
22	Gallup	103
23	Gila Cliff Dwellings National Monument	112
24	Kiowa National Grassland	52
25	Organ Mountains	125
26	Las Vegas National Wildlife Refuge	120
27	El Malpais	14
28	Reserve	117
29	Sandia Crest	106
30	Shiprock	84
31	White Sands National Monument	92
32	Crow Flats	102
33	Loco Hills	72
34	Santa Ana Pueblo	157
35	Navajo Lake State Park	114
36	Capulin	101
37	Arroyo Hondo	118
38	Alcalde	152
39	White Rock	123
40	Cañon Largo	116
41	Fenton Lake	86
42	The Caprock	92
43	Clines Corners	110
44	Rio Puerco	78
45	Mountainair	124
46	Corona	114
47	San Andres Mountains	134
48	Three Rivers Petroglyphs	126
49	Mayhill	118

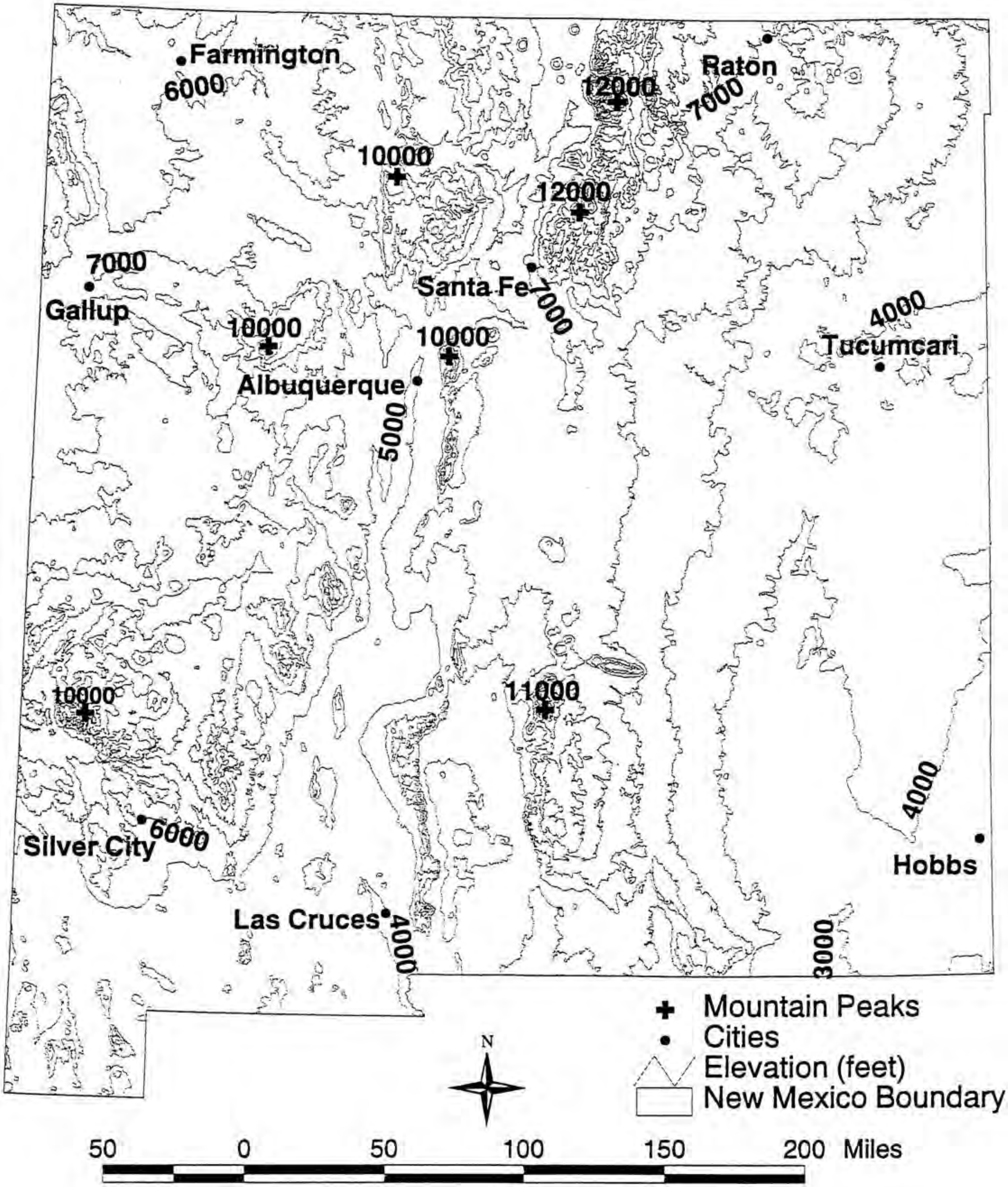
Bird Richness



New Mexico Rivers



1,000-foot Elevation Contours



(1000 feet = 300 meters; 100 miles = 161 kilometers)

23. Crane Migration

Description: Students act out the trip Sandhill Cranes make between their nesting habitats in Idaho and their winter home in New Mexico. They experience the hazards cranes face at either end of the migration path as well as along the way, seeing the importance of habitat to survival of cranes throughout the year.

Objectives: Students will:

- list the factors adversely affecting the population of Sandhill Cranes wintering in New Mexico;
- predict the effects of these restricting factors; and
- describe the effects of habitat loss and degradation on Sandhill Cranes and the importance of preserving wetland habitats for the cranes and other migrating water birds.

Materials:

- Large playing field or gymnasium
- Two bases for every three students; half at each end of playing area-

  Indoors: paper plates (clearly marked to differentiate top from bottom [i.e., paint one side blue to represent a wetland habitat and paint the other side brown to represent the loss of wetland habitat or write “habitat” on one side to represent wetland habitat and a large “X” for lost habitat]. Alternative materials are 12” x 12” carpet samples from carpet retail stores).

  Outdoors: cones or other objects as bases; e.g., use upright as “good wetland” and tip over for loss of wetland habitat.

Phenomenon: Cranes live in New Mexico in the winter, migrating in spring and fall.

Lesson Questions:

- *What do cranes need to survive through a year?*

23. *Crane Migration*

Grades: K-6

Time: two 30-minute sessions

Subjects: science, social studies

Terms: *behavioral adaptation, degradation, migration, staging area*

New Mexico STEM Ready! / Next Generation Science Standards
NGSS DCIs and New Mexico State Performance Expectations
K.LS1.C Organization for Matter & Energy Flow in Organisms
K.ESS3.A Natural Resources
K.ESS3.C Human Impacts on Earth Systems
1.LS1.A Structure & Function
1.LS1.B Growth & Development of Organisms
1.LS1.D Information Processing
3.LS1.B Growth & Development of Organisms
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
4.LS1.D Information Processing
5.LS1.C Organization for Matter & Energy Flow in Organisms
5.ESS3.C Human Impacts on Earth Systems
5.ETS2.A (5-SS-1 NM) Interdependence of Science, Engineering & Technology*
MS.LS1.B Growth & Development of Organisms
MS.LS2.A Interdependent Relationships in Ecosystems
MS.LS2.C Ecosystem Dynamics, Functioning & Resilience
MS.ESS3.C Human Impacts on Earth Systems
MS.ESS3.D Global Climate Change *

NGSS CCCs
Patterns; Cause & Effect: Mechanism & Explanation; Systems & System Models; Structure & Function; Stability & Change

NGSS SEPs
Asking Questions & Defining Problems; Developing & Using Models; Analyzing & Interpreting Data*; Constructing Explanations & Designing Solutions; Engaging in Argument from Evidence
(* indicates extension activity)

Background:

Every fall, the characteristic bugling call of the Sandhill Cranes can be heard along the Rio Grande, signaling the return of these magnificent creatures from their northern breeding grounds to their winter homes along the Middle Rio Grande Valley. Students living along the Valley will be familiar with the call and with the sight of cranes flying overhead. With their large size, loud calls, and tendency to hang out with large groups of peers, Sandhill Cranes are easy to observe and provide a captivating subject for student inquiry.

There are 15 species of cranes worldwide, 11 of which are considered threatened or endangered. Only two species, the Sandhill Crane (*Antigone canadensis*) and the Whooping Crane (*Grus americana*), live in North America. The Whooping Crane is the rarest of all crane species and is listed on the federal list of threatened and endangered species. More than 10,000 individuals may have been present prior to European settlement, but this number declined rapidly until they reached a low of 19 in 1945. Successful recovery efforts increased the U.S. population to over 600 by 2015; although they previously wintered in New Mexico there is no longer a local population.

This activity focuses on Sandhill Cranes. There are several subspecies of Sandhill Crane, with the Greater Sandhill Crane most abundant in the Middle Rio Grande Valley. Greater Sandhill Cranes stand 4.5 to 5 feet (1.4-1.5 meters) tall with a wingspan of six to seven feet (2–2.1 meters). They spend winters in New Mexico (as well as Texas, Arizona, California, and Mexico), but return to breeding grounds in the northern Rocky Mountains each spring. Lesser Sandhill Cranes are common in eastern New Mexico. Sandhill Cranes can fly from 15 to 50 miles per hour (24–80 kilometers per hour), often migrating 1,000 miles (1,600 km) or more each way.

Migration is a **behavioral adaptation** (actions organisms take to survive) that allows the cranes to find appropriate habitat at all times of the year. Whether in their winter home in New Mexico, in their breeding grounds in the north, or along their route in between, Sandhill Cranes spend much of their time in freshwater wetlands, including marshes, wet meadows, irrigated croplands, and river basins. These habitats are increasingly rare.

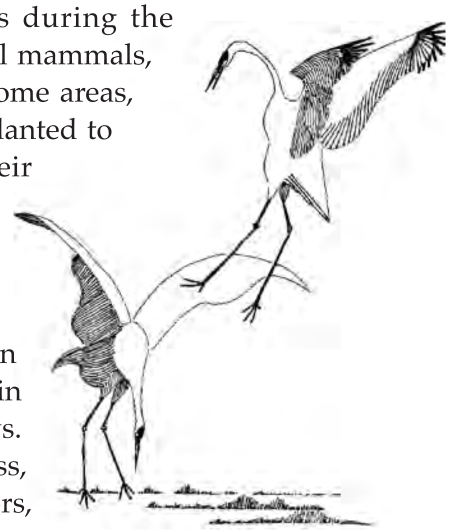
Most Sandhill Cranes that winter in the Middle Rio Grande Valley begin their migration in September from wetlands like those at Gray's Lake National Wildlife Refuge in Idaho. By the end of November, the majority of cranes that will winter in New Mexico have arrived; they start to leave again in mid-February. Many migrating cranes stop in the San Luis Valley of Colorado, at what is termed a **staging area**, to spend several weeks in the spring preparing for further migration. There they feed and socialize, and single birds choose partners before flying on to their northern nesting areas. The birds perform elaborate mating dances, which intensify during the breeding season but may be seen all year. Sandhill Cranes mate for life, so unless one partner dies, the pair stays together year-round. They typically build nests in small isolated wetlands, such as marshes, bogs, wet meadows and other areas with standing water. They use whatever vegetation is dominant, including cattails, sedges, bulrushes or grasses. While both sexes gather the vegetation, the female usually arranges the material. She usually lays two eggs, but typically only one nestling survives to fledge. Incubation takes about a month and the parents take turns sitting on the nest. Chicks are precocial, meaning they are born fully feathered, their eyes open shortly after hatching and they are able to walk within hours. The young chicks still require warmth, protection and feeding from their parents. By their second month, chicks become colts and begin pre-flight training. They begin foraging on their own in their third month, and are ready to migrate by the end of the summer. Family groups, including young of the year, migrate together, typically with other cranes. Unlike many smaller birds, cranes fly only during the day, usually at an altitude of about 2,500 feet (750 meters). They follow the same flyway they have used for centuries. Along the way they need wetlands where they can rest and eat before continuing their migration.

During migration and at their wintering grounds, cranes stay together in these large groups, which may number in the thousands of individuals. Group living provides many benefits, including increased flight efficiency, increased detection of predators and the decreased likelihood of any one individual being captured when among a large group. For example, when foraging in a group, individuals can share time watching for predators, so those not watching have more time to eat. Juveniles also benefit from staying with their parents by learning the migration route and the location of wintering sites.

Did you know?

- a juvenile crane is called a colt, adult male is roan, adult female is mare
- a group of cranes may be called a dance, a flock, a herd, a sedge, a siege, or a swoop

While in New Mexico, from late October through mid-February, cranes typically feed in open fields or along sandbars in or along the river during the days and roost in shallow water wetland areas at night. They are omnivorous, opportunistic feeders, eating primarily plants and grains during the winter but also feeding on invertebrates, small mammals, amphibians, and reptiles when available. In some areas, fields of grains, such as corn or triticale, are planted to support cranes, geese, and ducks during their winter stay in New Mexico, but recently there has been an effort to maintain and restore wetland areas as a way to provide natural foods for these birds, in addition to planting crops. Cranes use their stout bills to dig and probe in the ground for food and their long legs to wade in shallow water or walk through grassy meadows. When threatened, cranes spread their wings, hiss, and kick with their feet to deter their predators, which include raccoons, bobcats, coyotes, foxes, wolves, crows, ravens, eagles, and owls. Eggs, nestlings, and injured or sick adult cranes are most vulnerable to predation.



Cranes face numerous hazards throughout their annual cycle, but habitat loss remains the most significant as their preferred wetland habitats have been greatly reduced across their range. Prior to development during the 20th century, the natural flooding regime of the Rio Grande and the high water table in the Valley created rich wetland habitats along the floodplain. Humans began to use the river widely for irrigation and began adding flood control measures to protect their crops and homes; these changed the natural flooding regime of the Rio Grande. The installation of riverside drains lowered the water table and caused many wetlands to dry up. Today, the Rio Grande is confined to a small area within the floodplain, and many wetland areas where cranes and other birds used to live or stop during their migration have been converted to cities, towns, and farmland. Introduction of non-native plants, such as saltcedar and Russian olive, has also reduced the extent of wetlands. In addition to habitat loss, cranes are affected directly or indirectly by the use of pesticides and herbicides, predators, weather, fire, hazards during flight such as powerlines, and disease.

Like Whooping Cranes, populations of Sandhill Cranes declined dramatically after European settlement. In 1939, the Bosque del Apache National Wildlife Refuge was created as a safe place for birds (especially Sandhill Cranes) and other wildlife that migrate to the wetlands of the Middle Rio Grande for the winter. The refuge includes 13,000 acres (5,200 hectares) of bottomlands where the water of the Rio Grande has been diverted to create extensive wetlands. There are several other refuges in New Mexico, both state and local, that provide wintering wetland habitat as well. There are also international treaties and national laws protecting migratory species. State wildlife agencies share some responsibilities with the U.S. Fish and Wildlife Service, which is the regulating authority for managing and protecting migratory birds.

Through conservation efforts, including those at wildlife refuges like Bosque del Apache, the Sandhill Crane has made a comeback. In 1941, there were only 1,000 Greater Sandhill Cranes in the Rocky Mountain population, and 17 wintered at the Bosque del Apache. In 2016, the Rocky Mountain population of Sandhill Cranes was between 17,000 and 21,000. Sandhill Cranes are no longer considered endangered but their habitat is; if their habitat disappears, the cranes will disappear.

In this activity, students, acting as cranes, will "migrate" between their winter habitat in the wetlands of the Middle Rio Grande Valley to their nesting habitat at Gray's Lake in Idaho, while facing potential hazards along the way. Each student (assuming a class size of 25 to 30) represents 1,000 Sandhill Cranes. Thus, occasional losses due to predation and other minor events are not emphasized in the role play. The emphasis of the activity is on **habitat loss**. The main purpose of this activity is for students to dynamically experience some of the major destructive factors affecting Sandhill Crane habitats and the survival of the Sandhill Crane as a species.

Procedure:

Introduction:

- Have students make a KWL chart.

  Ask the question: *What do we **Know** about Sandhill Cranes and about habitat use by cranes? What do we **Want** to know about Sandhill Cranes?*

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

- You can also use the lens of **Systems** to learn about cranes in the bosque. For example, you can look at an individual crane as a system itself or the wintering flock of cranes in their habitat as part of a larger 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)**

Think of cranes in terms of systems. *What interactions do cranes have with other living things and non-living factors?* List them. *What environmental factors affect growth and development of cranes? If cranes cannot find places to rest and eat, whether at their breeding grounds, at their wintering grounds, or during migration, what happens?* **(MS.LS2.A)**

Steps:

- Begin by asking the students, *What do you know about Sandhill Cranes?* Students who live in the Valley will likely have seen cranes flying overhead in the spring and fall, but students living away from the river might not have this familiarity. There are many Sandhill Crane videos on YouTube or on the websites of National Wildlife Refuges that cranes visit that can give an idea about crane behavior (do an internet search for "Sandhill Crane," "Sandhill Crane migration," "Sandhill Crane wintering grounds," etc. Share information from the ***Background*** section to supplement students' knowledge.)
- Ask the students, *What factors affect the survival of Sandhill Cranes?* These include elimination of wintering, nesting, and migratory habitats due to development, such as building houses or industry, times of abundance or lack of food, drought, or floods. Students will learn of various limiting factors during the activity (see list below). **(3.LS2.C; 5.ESS3.C; MS.LS2.C; MS.ESS3.C)**
- Select a large playing area about 70 feet (21 meters) in length. Place one base for every three students at each end of the field. Designate one end as the "winter habitat" and the other as the "nesting habitat."
- Explain to the students that they are modeling Sandhill Cranes during their annual migration. They will migrate between the two areas at your signal.
    - In this model, each student represents 1000 cranes assuming a class size of 25 to 30. Adjust values as needed for your class size.
    - To increase interest, teach them the dance of the cranes. They bow their heads, flap their wings and leap high in the air. The cranes' dancing activity increases at the end of their stay at their winter habitats and then increases even more upon arrival at their nesting habitats in Idaho. Students can dance while waiting for the signal to migrate.
    - Tell them the bases represent wetlands. These wetlands provide a suitable habitat for the Sandhill Cranes. *Can you name any local wetlands?*

- Have them flap their wings. Cranes make a slow downbeat with a quick upbeat as they fly. They fly with their necks extended as they make their journey.
- At the end of each trip, the students will have to have one foot on a base in order to be allowed to continue. If they cannot get their foot on a plate, they have not found any suitable habitat, so they die and have to move, at least temporarily, to the sidelines and watch.
- Only three students (i.e., 3,000 Sandhill Cranes) can occupy a "habitat haven" (base) at any one time. (Adjust depending on number of students in the class.)
- Two students can be made permanent monitors to change the bases as per your instructions (see below).

Throughout the activity, you can ask questions and provide information about crane natural history, such as while the "cranes" are resting between rounds. For example:

What do cranes need in order to survive in each place they live during the year? What are cranes' habitat (food, water, shelter, space) needs? **(K.ESS3.A)**

Point out the seasonal pattern that the student "cranes" are portraying.

Why do cranes migrate? What causes them to move to different areas? **(Patterns; Cause & Effect: Mechanism & Explanation)**

All animals need food. *What food do cranes need and where do they find it?* **(K.LS1.C; 5.LS1.C)**

What parts of the crane help it to get food? To find a warm place to spend the winter? To escape predators? **(1.LS1.A; 4.LS1.A; Structure & Function)**

What senses do cranes use to tell if a predator is near? Then what actions do they take? What senses do cranes use to find food and water? **(1.LS1.D)**

How do crane parents help their young survive? How do they help their young successfully migrate? **(1.LS1.B)**

Crane parents lead juveniles along the migration route to the wintering grounds, and the young then follow the route back on their own.

*How do young cranes learn to migrate, including what route to take? (*They follow their parents south the first year, then can find their way back north on their own. They follow the same path in future years on their own. They are using perception and memory to guide their actions.) **(4.LS1.D)**

What behaviors do cranes have that increase their odds of reproduction? What courtship and pair bonding behaviors do cranes have? **(3.LS1.B; MS.LS1.B)**

How does traveling in a group affect cranes' survival? **(3.LS2.D)**

What dangers are there for Sandhill Cranes? What predators are looking for cranes, and where and how are predators typically successful?

Eggs, nestlings, and injured or sick adult cranes are most vulnerable to predation. Predators include raccoons, bobcats, coyotes, foxes, wolves, crows, ravens, eagles, and owls. Cranes are particularly vulnerable at night while resting; they typically stand in water so they can hear predators approaching. Predators weed out sick animals, which can help keep diseases from spreading to other cranes. **(MS.LS2.A)**

Consider carrying capacity. *What resources might be limited as cranes migrate south and winter in New Mexico? What is the result to crane populations when resources are limited?* **(3.LS2.C; MS.LS2.A; MS.LS2.C)**

- Begin the activity at the wintering habitats in New Mexico. The students will be doing the dance of the cranes. Signal the start of the first migration. Have the students migrate in slow motion until they become familiar with the process. Then they can speed up. On the first try, all the birds will migrate successfully to the nesting habitat.
- Explain that there is sufficient nesting habitat for all the migrating cranes. Thus, the students can do the crane dance and begin a successful nesting season.
- Turn over one base in the wintering region. Explain that a large wetland area has been drained and used for agricultural purposes. Repeat the signal to migrate and send the cranes on their journey to southern and central New Mexico for the winter. Have the three displaced students stand on the sidelines. Remind the students that these three represent 3,000 cranes. Thus these 3,000 died as a result of habitat loss. Let the students playing dead birds know that they can get back in the activity as surviving hatchlings when conditions are favorable and habitat is available in the nesting ground. **(3.LS2.C; MS.LS2.C)**
- Before the next migration to the northern nesting area, turn over four plates in that area. Tell the students there was a catastrophic forest fire, which has severely polluted and damaged wetlands. **(3.LS2.C; MS.LS2.C)** Give the dancing cranes the signal to migrate. At least 12 students will not find nesting habitat. Note: this results in a large number of students waiting on the sidelines. Before many cycles are repeated, provide them with an opportunity for re-entry in the nesting habitat. Each time, give the students examples of changes in habitat conditions that make increases in population possible. For example, the Valle de Oro NWR has constructed new wetland habitat for wading and shore birds (see below). **(K.ESS3.C; 3.LS4.D; 5.ESS3.C; MS.ESS3.C)**
- Repeat the process for eight or 10 migration cycles to illustrate changes in habitat conditions that affect the cranes. See the lists below for suggestions of human-caused factors that might influence the Sandhill Cranes' survival.

Factors **limiting** the survival of Sandhill Cranes:

- wetland drainage
- drought, causing less available food and drying out of wetlands
- pollution and contamination of water
- pollution of food on which cranes feed
- urban expansion
- conversion of wetlands to non-crane-friendly farm lands
- conversion of natural waterways to canals
- diseases such as avian cholera
- conversion of wetlands to developments, industrial or residential
- not wanting wildlife to feed in agricultural fields
- illegal hunting (poaching)
- crane flies into power line and is killed or severely injured

Factors **favoring** the survival of Sandhill Cranes:

- human action aimed at preservation of wetlands
- wildlife forage crops, such as corn or alfalfa, left for wintering birds (such as at Los Poblanos farm and Los Poblanos Open Space in Albuquerque, farmers in Valencia County)
- civic action aimed at habitat conservation and restoration (e.g., building wetlands where they used to be)
- education programs to appreciate wetlands and wetland species
- regulation of hunting and reduced poaching

Although some limiting factors to the cranes' survival are a natural part of any environment, the largest threat to these big birds seems to be the loss or **degradation** of suitable habitat, most often as a result of human actions such as draining wetlands and pollution.

Be sure to create one or more "disaster" years to illustrate catastrophic loss of large areas of available habitat. Remember that wetland habitats are diminishing both locally and worldwide, so the activity should end with fewer areas of available habitat than can accommodate all the cranes. The result is a smaller population of cranes locally and worldwide. **(3.LS2.C; MS.LS2.C)**

Cranes need certain habitats to survive: in their nesting area, during migration, and at their wintering areas. *What habitats do cranes need to survive?* **(K.ESS3.A; 3.LS4.C)**

In this activity, we have seen some human-caused changes to the habitat that cranes need during their life cycle: in their nesting area, during migration, and at their wintering areas. *How do human-caused changes in any of those areas of habitat affect the cranes? What habitat changes, both good and bad, did we see?* Humans can decide what changes they make to the environment, including avoiding those that may affect wildlife and habitat. *Can you think of an example where humans thought about building, clearing, or somehow affecting habitat, but then decided not to? Have you heard of past pollution that has been reduced or eliminated?*

What are things that individual people and communities can do to help protect cranes and the places where they live and travel? Can you think of ways people can protect Earth's wildlife and environments? **(K.ESS3.C; 3.LS4.D; 5.ESS3.C; MS.ESS3.C; Stability & Change)**

Play several rounds of the game recording population changes for each round.

Assessment:

- Evaluate the accuracy of this activity as a model of annual crane migration. *In what ways does this model do a good job of describing crane migration? How is it inadequate or inaccurate? How could it be improved?*
- Have students choose among the following:
    - Write a story as if you were a crane. Explain what happened to you and your flock over your many migrations.
    - Draw a series of pictures about what happens to you and your flock.
    - Give a presentation to someone in your family about crane migrations.
    - Show your understanding of the life cycle of Sandhill Cranes through a drawing, writing, or other creative means. **(3.LS1.B)**
    - Draw or make maps of the migration routes. *How can models such as these maps be used to provide information on and explanations of crane activity? What are the limitations of such models?* **(Developing & Using Models)**
- Have the students write a summary of the ideas generated during the discussion. Be sure to have them distinguish between the human-caused factors and the environmental factors involved in the success or decline of the crane's population. Working from the students' summaries, generate a class list of factors causing population increases or declines. Compare the similarities and differences between these limiting factors. Finalize the discussion by having the students identify the factors that pose the most significant long-term threat to the survival of the Sandhill Crane. **(Patterns; Cause & Effect: Mechanism & Explanation; Constructing Explanations & Designing Solutions)**
- Discuss what kinds of things can and should be done to protect the wetland habitats necessary to the survival of the Sandhill Crane and all migratory birds. Discuss the compromises and trade-offs related to different recommendations. *Are there multiple solutions to the problem?* Gather facts and support the recommended solutions you put forward. **(Constructing Explanations & Designing Solutions; Engaging in Argument from Evidence)**

Extensions:

- Have the students think about a low population of cranes. How might they show that the Rocky Mountain flyway had a population of only 1000 Sandhill cranes in 1941 when Bosque del Apache National Wildlife Refuge was just created. *How does that refuge and others help increase the Sandhill Crane population?*

- Use a graph to chart the declines and increases in crane population size that were observed during the crane migration activity. After the activity the students can be asked to:
    - identify the apparent causes of any changes in population from year to year;
    - identify the major factors contributing to habitat loss and degradation;
    - make predictions about the effects of these factors;
    - distinguish between short-term and long-term effects;
    - distinguish between catastrophic and gradual changes; and
    - support their ideas with evidence, engaging in research if necessary. **(Analyzing & Interpreting Data; Engaging in Argument from Evidence)**

- Take a trip to see cranes during their winter stop in New Mexico. Possible locations include (directions and visiting information available online):
    - Bosque del Apache National Wildlife Refuge (south of Socorro)
    - Bernardo Wildlife Area (between Belen and Socorro)
    - Los Poblanos Open Space (North Valley, Albuquerque)
    - Bitter Lake National Wildlife Refuge (near Roswell)
    - Grulla National Wildlife Refuge (near Portales)
    - Whitfield Wildlife Conservation Area (Valencia County)

- Make videos of cranes at a refuge or other location.
- Have older students lead primary students in the Crane Migration activity
- Watch videos of cranes dancing and calling to their mates. *Why do cranes make loud calls? How can cranes make such loud calls?* Research crane vocalizations. Students should find that cranes have specially adapted tracheas to help them with their calls. **(3.LSI.B; 4.LS1.A; MS.LSI.B)**
- Research the possible effects of climate change on Sandhill Cranes and their migration or on other migrating species. Biologists must now consider climate change as they predict the impacts of human activities on wildlife species. **(MS.ESS3.D)**
- Research New Mexico biologists who study Sandhill Cranes, other wildlife or wetland ecology. This will address New Mexico Specific Standard/ Performance Expectation about Science and Society. **(5.ETS2.A; 5-SS-1.NM)**

(above) Sandhill Cranes with "landing gear" down,
settling in for the night in the Rio Grande in Albuquerque

photos by Laurel Ladwig

Resources and References:

Elphick, C., J.B. Dunning, D.A. Sibley, eds. 2001. The Sibley Guide to Bird Life and Behavior. National Audubon Society/ Alfred A. Knopf, New York.

Aquatic WILD K-12 Curriculum & Activity Guide. 2013. Council for Environmental Education., Bethesda, MD.

Price, Alice Lindsay. 2001. Cranes the Noblest Flyers: In Natural History & Cultural Lore. La Alameda Press, Albuquerque, NM.

Bosque del Apache National Wildlife Refuge. 1996. Southwest Natural and Cultural Heritage Association, Albuquerque, NM.

The International Crane Foundation at http://www.savingcranes.org

NGSS Connections to Crane Migration—Disciplinary Core Ideas

K.LS1.C Organization for Matter and Energy Flow in Organisms *All animals need food in order to live and grow. They obtain their food from plants or from other animals.*
All animals need food. *What food do cranes need and where do they find it?*

K.ESS3.A Natural Resources *Living things need water, air and resources from the land, and they live in places that have the things they need. Humans use natural resources for everything they do.*
What do cranes need in order to live in each place they live during the year? What are cranes' habitat (food, water, shelter, space) needs?

K.ESS3.C Human Impacts on Earth Systems *Things that people do to live comfortably can affect the world around them. But they can make choices that reduce their impacts on the land, water, air, and other living things.*
Humans can decide what changes to make in the environment, including avoiding those that may affect wildlife and habitat. *Can you think of an example where humans thought about building, clearing, or somehow affecting habitat, but then decided not to? Have you heard of past pollution that has been reduced or eliminated?*

1.LS1.A Structure and Function *All organisms have external parts. Different animals use their body parts in different ways to see, hear, grasp objects, protect themselves, move from place to place, and seek, find, and take in food, water, and air.*
Use cranes as an example to address this standard. *What parts of the crane help it to get food? To find a warm place to spend the winter? To escape predators?*

1.LS1.B Growth and Development of Organisms *Adult plants and animals can have young. In many kinds of animals, parents and the offspring themselves engage in behaviors that help the offspring survive.*
Crane parents take care of their young by feeding them, teaching them to find food themselves, and then leading them on their first migration south. Once they travel the route once, they make the return trip north on their own. *How do crane parents help their young survive? How do they help their young successfully migrate?*

1.LS1.D Information Processing *Animals have body parts that capture and convey different kinds of information needed for growth and survival. Animals respond to these inputs with behaviors that help them survive.*
What senses do cranes use to tell if a predator is near? Then what actions do they take? What senses do cranes use to find food and water?

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.*
Using cranes as an example, look at the dances parent cranes do to reinforce their lifetime pair bond. Have students show their understanding of the life cycle of Sandhill Cranes through a drawing, writing, or other creative means. *What behaviors do cranes have that increase their odds of reproduction? What courtship and pair bonding behaviors do cranes have?*

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 focuses on the effect of habitat loss (i.e., changes to the environment) on the survival of Sandhill Cranes. Changes include elimination of wintering and nesting habitats because of development, such as houses or industry, times of abundance or lack of food, drought, or floods. *What changes to the environment limit the survival of Sandhill Cranes? What resources might be limited as cranes migrate south and winter in New Mexico? What is the result to crane populations when resources are limited?*

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.*
Sandhill Cranes live and travel in flocks. *How does traveling in a group affect cranes' survival? Do cranes take on different roles in a group? Does the same bird always lead in their "V" formation flights?*

3.LS4.C Adaptation *For any particular environment, some kinds of organisms survive well, some survive less well, and some cannot survive at all.*
Cranes need certain habitats to survive: in their nesting area, during migration, and at their wintering areas. *What habitats do cranes need?*

3.LS4.D Biodiversity and Humans *Populations live in a variety of habitats, and change in those habitats affects the organisms living there.*
In this activity, we have seen some human-caused changes in the habitats that cranes need during their life: in their nesting area, during migration, and at their wintering areas. *How do human-caused changes in any of those areas of habitat affect the cranes? What habitat changes, both good and bad, did we see?*

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.*
Use cranes as an example to address this standard. *What parts of the crane help it to get food? To find a warm place to spend the winter? To escape predators?*
Extension: Watch videos of cranes dancing and calling to their mates. *Why do cranes make loud calls? How can cranes make such loud calls?* Research crane vocalizations. Students should find that cranes have specially adapted tracheas to help them with their calls.

4.LS1.D Information Processing *Different sense receptors are specialized for particular kinds of information, which may then be processed by an animals' brain. Animals are able to use their perceptions and memories to guide their actions.*
How do young cranes learn to migrate, including what route to take? They follow their parents south the first year, then can find their way back north on their own. They follow the same path in future years on their own. They are using perception and memory to guide their actions.

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.*
All animals need food. *What food do cranes need and where do they find it?*

5.ESS3.C Human Impacts on Earth Systems *Human activities in agriculture, industry, and everyday life have had major effects on land, vegetation, streams, oceans, air and even outer space. But individuals and communities are doing things to help protect Earth's resources and environments*.
Human impacts on crane survival include elimination of wintering and nesting habitats because of development, such as houses or industry, times of abundance or lack of food, drought, or floods. *What factors limit the survival of Sandhill Cranes?What are things that individual people and communities can do to help protect cranes and the places where cranes live and travel? Can you think of ways people can protect Earth's wildlife and environments?*

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 Crane Migration activity.

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.
Each year biologists make important contributions to our understanding of New Mexico's wildlife. This activity can inspire students to learn more about these wild species as well as about the people who study their ecology and what the animals need to survive here. Challenge your students to learn about some of these dedicated scientists.

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.

SEP: Obtaining, Evaluating & Communicating Information

MS.LS1.B Growth and Development of Organisms *Animals engage in characteristic behaviors that increase the odds of reproduction.*
Using cranes as an example, look at the dances parent cranes do to reinforce their lifetime pair bond. *What behaviors do cranes have that increase the odds of reproduction? What courtship and pair bonding behaviors do cranes have? Why do cranes make loud calls? How can cranes make such loud calls?*

MS.LS2.A Interdependent Relationships in ecosystems *Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with non-living factors.*
-Growth of organisms and population increases are limited by access to resources.
-Similarly, predatory interactions may reduce the number of organisms or eliminate whole populations of organisms. Mutually beneficial interactions, in contrast, may become so interdependent that each organism requires the other for survival.
Although the species involved in these competitive, predatory, and mutually beneficial interactions vary across ecosystems, the patterns of interactions of organisms with their environments, both living and nonliving, are shared

.Think of cranes in terms of systems. *What interactions do cranes have with other living things and non-living factors?* List them. *What environmental factors affect growth and development of cranes? If cranes cannot find places to rest and eat on their migration, what happens?* Consider carrying capacity. *What resources might be limited as cranes migrate south and winter in New Mexico? What is the impact on crane populations when resources are limited?*
Cranes are particularly vulnerable at night while resting; they typically stand in water so they can hear predators' approach. Bobcats will try to catch cranes. If they are sick or injured, coyotes will chase them and will catch vulnerable cranes. If predators catch sick animals, this can help keep diseases from spreading to other cranes. *What dangers are there for Sandhill Cranes? What predators are looking for cranes, and where and how are predators typically successful?*

MS.LS2.C Ecosystem Dynamics, Functioning and Resilience *Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations.*

This activity looks at disruptions to physical and biological components of the crane's habitat throughout its annual life cycle. Disruptions include elimination of wintering and nesting habitats because of development, such as houses or industry, times of abundance or lack of food, drought, or floods. *What factors limit the survival of Sandhill Cranes? What resources might be limited as cranes migrate south and winter in New Mexico?*

MS.ESS3.C Human Impacts on Earth Systems *Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things.*

--Typically, as human populations and per capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.

Human impacts on crane survival include elimination of wintering and nesting habitats because of development, such as houses or industry, times of abundance or lack of food, drought, or floods. *What factors limit the survival of Sandhill Cranes?What are things that individual people and communities can do to help protect cranes and where they live and travel? Can you think of ways people can protect Earth's wildlife and environments?*

MS.ESS3.D Global Climate Change *Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and the other kinds of knowledge, such as understanding of human behavior, and on applying that knowledge wisely in decisions and activities.*

Extension: Research the possible effects of climate change on Sandhill Cranes and their migration or other migrating species. Biologists must now consider climate change as they predict the impact of human activities on wildlife species.

(right) Sandhill Cranes dancing at Valle de Oro National Wildlife Refuge

photos by Laurel Ladwig

24. Invasive Species

Description: Students work in teams of two to research invasive species in the bosque to develop a management plan for a fictional wildlife refuge. Then, students develop recommendations for improving the situation at the refuge and produce a presentation of their recommendations.

Objectives: Students will:

- search for biological resource information;
- understand how invasive species affect an ecosystem; and
- prepare a basic species management plan.

Materials:

- Computers with internet access (one for each team of two students)
- Copies of student activity pages
- Supplies for making posters or software for creating computer presentations

Phenomena: There are species of plants and animals living in the bosque that have never been here before; invasive species are outcompeting native species for habitat.

Lesson Question:

- *How can a wildlife refuge manage invasive species to benefit native ones?*

24. Invasive Species

Grades: 6-12

Time: three hours for internet research; two hours for writing management plan; time for class presentations

Subjects: science

Terms: *alien species, exotic species, introduced species, invasive species, native species, non-native species, noxious species, webography/webliography*

New Mexico STEM Ready! / Next Generation Science Standards

NGSS DCIs and New Mexico State Performance Expectations

MS.LS2.A Interdependent Relationships in Ecosystems
MS.LS2.C Ecosystem Dynamics, Functioning & Resilience
MS.ESS3.C Human Impacts on Earth Systems
MS.ESS3.D Global Climate Change*
HS.LS2.C (HS-LS2-7 NM) Ecosystem Dynamics, Functioning & Resilience
HS.LS4.D (HS-LS2-7 NM) Biodiversity & Humans
HS.ESS3.C Human Impacts on Earth Systems
HS.ESS3.D Global Climate Change*
HS.ETS1.A (HS-SS-2 NM) Defining & Delimiting Engineering Problems
HS.ETS1.B (HS-LS2-7 NM & HS-SS-2 NM) Developing Possible Solutions

NGSS CCCs

Patterns; Cause & Effect; Structure & Function; Stability & Change

NGSS SEPs

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

(* indicates extension activity)

Terms

Native species: an organism indigenous to a particular area, occurring within its natural range or within the area in which it evolved.

Non-native/exotic/introduced/alien species: these are all terms used to describe an organism occurring outside its natural range. Such species are not necessarily invasive but may be neutral or even beneficial. Some introduced species become invasive.

Invasive species: a species not native to the ecosystem and whose introduction causes or is likely to cause economic or environmental harm or harm to human health. Invasive species are able to establish, persist, and spread widely outside their natural range. They can be plants, animals, or other living organisms. Human actions are the primary means of invasive species introductions.

Noxious species: an organism that is likely to cause harm in an ecosystem or natural habitat, to agricultural or horticultural crops, to native species, humans or livestock. Noxious species may be native.

NOTE: Refer to the “Changing River” activity for more information on non-native species.

Background:

Exotic, or non-native species are widespread throughout the world. These include plants, animals and microbes that are established outside their native ranges, typically spread by the actions of humans. Many such species are benign, causing no significant problems in their new homes, while some are even beneficial, such as the honeybee. Others, however, cause extensive ecological or economic harm in their new environment. We call these invasive species, and they can reduce the biological diversity in an area, sometimes causing native species to go extinct or altering the habitat in such a way that native species are pushed away.

Land managers grapple with how to treat exotic species. In most cases, exotic species cannot be eliminated, and species that do not cause great harm are left to become part of the altered ecosystem. Attempts are often made to control invasive species that wreak havoc on native ecosystems, but in some cases, even invasive species that have caused environmental harm may be, if not welcomed, then at least accepted as part of the local ecosystem. For example, many exotic plants have become so widespread that removing them may be impossible. In this activity, students will wrestle with the challenges that land managers face in dealing with invasive species.

The local bosque ecosystem now supports numerous exotic species. Some do not cause great environmental harm and may even benefit native species, as in the case of mulberry benefitting fruit-loving birds and other animals. In contrast, saltcedar (or tamarisk) has completely replaced the native bosque trees in many areas, creating extensive monotypic (one species) stands that reduce available nesting habitat for birds and promote the spread of wildfire. Intentionally introduced as an ornamental in the early 1800s, saltcedar was soon also used to create windbreaks and to control erosion along river banks, including along the Rio Grande. It quickly spread throughout western riparian systems, causing lasting environmental changes. Millions of dollars have been spent as land managers have tried numerous methods to eradicate saltcedar, with limited success. The story became more complicated when it was discovered that, in some areas, the federally endangered Southwestern Willow Flycatcher (a Species of Greatest Conservation Need in New Mexico) was nesting in these monotypic stands. It turns out that these birds were not as picky as once thought and were successfully using saltcedar where no other trees were available. This created an unexpected complication for land managers once determined to remove this invasive species. [See "Introduced and Non-Native Species" and the "Tale of Two Exotics" sidebar in Activity #15 "Who Lives Where?" for one more unexpected twist in this exotic tale.]

In discussing exotic and invasive species, encourage students to consider why a species was introduced. In many cases, such as the invasive shrub saltcedar, the introduction made sense at the time, serving some ornamental or utilitarian purpose. It was only later that unforeseen effects were realized. In contrast, some species were introduced accidentally. That was the case for the small crustaceans called isopods (*Armadillidium vulgare* and *Porcellio laevis*), that were introduced from the Mediterranean region in soil used as ballast in ships sailing to North America. The ships dumped their ballast as they loaded cargo to return to Europe, and now these isopods occur across the United States. It's important to understand that people have made mistakes, although they weren't always intentional. Now, in many cases, we are dealing with the consequences.

Consider also how introduced species respond to disturbances in the landscape, particularly in comparison to native species. Do they recover quickly after a fire? After flooding? Have they become invasive because they can recover quickly after a disturbance, whether human-caused or natural? Tumbleweed and puncture vine grow well where soil has been disturbed, while saltcedar recovers quickly after fire and does well as the climate dries and warms. Disturbance is part of the bosque ecosystem, so understanding how it affects both native and introduced species is important. See Activity #13 "Changing River" for more about disturbance in this ecosystem.

How are students affected by introduced species? In this activity they will develop management plans to deal with invasive species in fictional wildlife refuges. To relate to the need for such management, students should consider how they themselves are affected by invasive species. Saltcedar increases the risk of fires in the bosque. Do bosque fires put homes at risk? How do fires affect the impact of flooding? Have students ever stepped on a goat head, had one puncture a bike tire, or get stuck in their dog's paw? Students whose families enjoy recreational boating may have heard of invasive Zebra and Quagga mussels. Care must be taken by boaters to prevent the spread of these invasive aquatic species. Introduced species may affect us in many ways.

In this activity, you will challenge your students to understand the complexities of invasive species, the impacts on our local areas, and how those impacts might be reduced in our special nature reserves.

Overview of Activity:

1. Introduce invasive species and issues of concern regarding them in wildlife areas of New Mexico.
2. Practice internet research and documentation skills using Oryx as an example for class collaborative research.
3. Team Projects - Create and present management plans.
   - Step 1. Assign each team an invasive or noxious species to research. As a team, they will locate websites or webpages about their species, documenting their sources as they go. *(student handout)*
   - Step 2. Using these sources, each team will prepare a species profile. *(student handout)*
   - Step 3. Student teams write management plans based on research. *(student handout)*
   - Step 4. Teams will present management plans to the class. They may do a computer presentation or a poster with appropriate drawings and illustrations.
   - Step 5. Evaluate teams' work. *(student handout)*

Make sure that computers are available and working with internet connection.

Procedure:

1. Introduce Exotic/Invasive Riparian Species in New Mexico

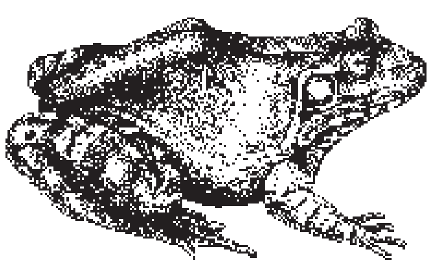
NOTE: Prior to this activity, we suggest doing the #13 "Changing River" model activity with the class. Make sure to do the Rio Bravo and Rio Manso sections. Add invasive animals and plants to the model with #15 "Who Lives Where?" and #16 "Who Grows Where?" activities. Discussing those non-native/invasive species through the included animal and plant cards will lay a strong foundation for this activity.

- Begin with a discussion of introduced plants. *What non-native plants have students seen around their neighborhoods? What about tumbleweed? Kochia? Anyone have a dog that gets stickers in their paws?* These are often goat heads or "toritos" (little bulls!) and are also known as puncture vine or caltrops; many names for this spiky-seeded plant. *How are students affected by non-native plants?*
- Developing a KWL chart can help organize student knowledge. **(Asking Questions & Defining Problems)**
- Now consider our wildlife refuges. Are there any threats to these protected areas? Let's brainstorm ideas about any threats to wildlife refuges and other natural spaces such as national forests, wilderness areas, public lands and non-government preserves. Encourage discussion of any problems, but be sure students recognize that invasive plants and animals pose significant threats in many areas.

> **Refuges in New Mexico**
>
> There are many protected areas in New Mexico, managed by national, state, and local entities. These include National Wildlife Refuges, National Parks, National Forests, State Wildlife Management Areas, State Parks, BLM land, private conservation areas and more. Have students search for examples of protected areas near you.

- Teachers or students can look up the U.S. Department of Agriculture National Invasive Species Information Center (NISIC) for information on invasive species, including photos. https://www.invasivespeciesinfo.gov/

The Rock Snot example (next page) can be shared with students as a brief introduction.



ROCK SNOT?!! What's that?

Didymosphenia geminate, commonly known as **didymo** or rock snot, is a freshwater diatom (a type of algae) native to cool, low-nutrient streams and lakes in northern parts of North America, Europe, and Asia. Since the 1980s, something in its physiology has changed that has allowed didymo to inhabit a wider range of temperature and nutrient conditions. Didymo now often forms large, nuisance blooms, and what's more, the species has spread throughout the world, including into the Southern Hemisphere. Its slimy appearance gives rise to the nickname, rock snot. Under certain conditions, it produces thick, branching stalks that join together to create large, carpet-like mats up to eight inches (20 cm) thick and capable of covering plants, rocks, and other hard surfaces. These tan mats look like clumps of wet toilet paper and can smother plants, insects, and mollusks along several miles of a stream or river, altering aquatic habitats and disrupting food chains. This affects humans directly by decreasing recreational opportunities, such as fishing and swimming. In fact, it is likely human activity has caused the spread of didymo, since it attaches to recreational equipment, especially felt-soled boots and waders. Anglers, boaters, or swimmers moving from one stream to another can unknowingly transport this tiny creature, with huge consequences.

As of 2021, didymo has been found in some upper headwater streams in New Mexico, but its range is currently limited. Please help prevent the spread of this potentially invasive species by checking gear and clothing for clumps of algae when you leave the river. Don't wash them down the drain! Throw clumps in the trash or away from water where they will dry out and die. Soak and scrub anything that has been in contact with the algae for at least one minute in either hot water (140°F/60°C), a 2% solution of household bleach, or a 5% solution of salt, antiseptic hand cleaner, or dishwashing detergent. Alternately, dry out gear for at least 48 hours before using it in a different waterway. Your help is needed to prevent the spread of rock snot!

2. Practice Using Strong Internet Research and Documentation Skills
Now work together as a class to develop students' research and documentation skills as you research the Oryx *(Oryx gazella)* in New Mexico. Oryx were introduced into the White Sands Missile Range in the late 1960s to provide exotic big-game hunting experiences, but they soon proved to be too successful in their new home. Students can learn more about this introduction and its ramifications, but the real emphasis here is to help students build strong internet research skills. Students will use these skills as they research their invasive species and develop their own management plan.

Clarify Your Search and Define Your Question

First have students consider what information they are seeking. What are their questions? Brainstorm effective keywords, consider synonyms, alternative phrases, etc. It is good to start simple and then get more specific.

For the Oryx example, we suggest finding the following information:

- Physical description (including type of animal, size, physical characteristics)
- Where are Oryx native? Where do they occur in New Mexico?
- How did Oryx arrive in New Mexico?
- What are the consequences of being in New Mexico? Have they done any damage?
- Are there any benefits to Oryx being in New Mexico?

(The goal will be for the class to outline a plan for managing Oryx in New Mexico; see step d.)

Evaluate Resources
It is usually easy to find many resources when using the internet, but how do students know if the resources are legitimate or useful for their research? Students can apply the CRAAP test, developed by librarians at California State University, Chico's Meriam Library (licensed under a Creative Commons Attribution 4.0 International License https://creativecommons.org/licenses/by/4.0/)

CRAAP Test acronym stands for:
Currency: The timeliness of the information.
Relevance: The importance of the information for your needs.
Authority: The source of the information.
Accuracy: The reliability, truthfulness, and correctness of the content.
Purpose: The reason the information exists.

Find the full version for questions to guide students in this evaluation here: https://library.csuchico.edu/sites/default/files/craap-test.pdf

Document Resources
Just as with books or other printed material, it is important to document any source of information that is not original when using material gathered via the Internet. A ***webography*** is a list of websites that pertain to a particular topic. The term ***webliography***, adapted from the term *bibliography*, is similar and may also be used. Depending on your goals and your students' level, you may choose to require the full Council of Science Editors (CSE) style format or a simpler version. Examples of both are below. NOTE: frequently,

complete citation information is not available for internet sources, so tell students to just make their best effort in collecting this material. Gathering the information will help students assess the validity of the resource.

1) Simple Documentation of Research (suggested for younger students)

Documentation will include the following information:

URL (address):
Who sponsors or hosts this web page?
Who is the intended audience?
Information addressing your question

Oryx Simple Example:

URL (address): https://animaldiversity.org/accounts/Oryx_gazella/
Who sponsors or hosts this web page? University Michigan Museum of Zoology,
Who is the intended audience? General public
Information addressing your question (answers will vary)

2) Advanced Documentation of Research using the Council of Science Editors (CSE) style (suggested for older students)

The citation should include the following information:

Author's name (last name, first initials; if known)
Date of publication or last revision
Title of website (Online)
Place of publication (City [State initials]) and publisher name/organization
Title of web page/document
Update and/or access date
[updated year, abbreviated month day; cited year, abbreviated month day)
URL (address)
Information addressing your question

The Oryx citation could include the following information:

Author's name Sanders, S.
Date of publication or last revision 2005
Title of website Animal Diversity Web
Place of publication and publisher name Ann Arbor MI: University of Michigan
Title of web page/document Oryx gazella gemsbok
Update and/or access date 11-09-2021
URL https://animaldiversity.org/accounts/Oryx_gazella/
Information addressing your question (answers will vary)

Using the above information, the format for including a CSE style citation in a written document is as follows:

Author last name, first/middle initials. (year published). Title of website (Online). Publication city(state): Publisher/Organization. Title of web page [updated year abbreviated month day; cited year abbreviated month day]. Available from: URL

Oryx CSE style example for citation in a document:

Sanders, S. 2005. "Oryx gazella" (Online), Animal Diversity Web. Accessed November 09, 2021 at https://animaldiversity.org/accounts/Oryx_gazella/

Outline a plan for managing Oryx in New Mexico.

- List at least three methods for management, one being no action.

3. Team Projects

Step 1. Assign students to teams of two and assign each team a noxious/invasive plant species (invasive aquatic animals and additional plant options are listed in *Extensions*):

Cheatgrass, *Bromus tectorum*
Kochia, *Kochia scoparia*
Sweet clover, *Melilotus alba*
Russian olive, *Elaeagnus angustifolia*
Saltcedar, *Tamarix chinensis*
Siberian elm, *Ulmus pumila*
Tree of heaven, *Ailanthus altissima*

- Pass out the Invasive Species student pages; choose either the short version or CSE style version for documentation page. Teams will locate websites or webpages with information about their species, documenting sources as in the Oryx example. *(student handout)*
- Provide students with a timeline for completing their research.
- Facilitate student groups, helping to troubleshoot technology problems, asking questions, and helping them to organize their work.

Step 2. Students create species profiles.

During their research, considering questions like the following will help students address particular standards:

If a new organism is added to an ecosystem, how does it interact with species that were there already? If there are introduced predatory animals in an ecosystem, how might they affect native animals? **(MS.LS2.A)**

How do invasive species disrupt an ecosystem? What kinds of shifts in populations of other species can be seen? How would invasive species affect the biodiversity of an ecosystem? **(MS.LS2.C)**

How have human activities regarding invasive species impacted habitats or other species (positively and negatively)? **(MS.ESS3.C)**

When invasive species are introduced by humans, how are ecosystems disrupted? How is the survival of native species threatened? **(HS.LS2.C)**

How do humans depend on the biodiversity of natural ecosystems? **(HS.LS4.D)**

Invasive species often have negative impacts on ecosystems. *How can scientists and/or engineers help prevent ecosystem degradation by invasive species?*

What would be involved with restoring habitat in this location—in this example, managing invasive species to ensure native species can thrive in this area?

How can humans help to sustain the biodiversity of native ecosystems?

Think of examples where a reduction in invasive species can help the natural biodiversity in an area. **(HS.ESS3.C)**

(Above questions may address: Cause & Effect; Structure & Function; Stability & Change; Constructing Explanations & Designing Solutions; Engaging in Argument from Evidence)

Since your students will be learning about a specific species, they should be able to explain the adaptations and specific characteristics that allow its survival (i.e., their species' structures and functions). *How do the structures of your species help the function of that species?* **(Structure & Function)**

Step 3. Write a management plan. See student page for details.

This activity can specifically address **NM Specific State Performance Expectations**.

By researching, writing and presenting a management plan for addressing invasive species in a nature reserve in New Mexico, your students can address:

HS-LS2-7 NM. Using a local issue in your solution, design and analyze the advantages and disadvantages of human activities that support the local population such as reclamation projects, building dams, and habitat restoration.

HS-SS-2 NM. Construct an argument using claims, scientific evidence, and reasoning that helps decision makers with a New Mexico challenge or opportunity as it relates to science.

See detailed explanations in the **NGSS Connections to Invasive Species – Disciplinary Core Ideas** section below.

(HS.LS2.C; HS.LS4.D; HS.ESS3.C ; ETS1.A; ETS1.B;)

Step 4. Student teams present their plans to reduce the impact of their invasive species to their fellow students. A typical management plan is a written report, with highlights given to agency staff and/or in a public meeting with a computer presentation. You may allow other formats such as posters. **(Obtaining, Evaluating & Communicating Information)**

Assessment:

Step 5. Use the rubric found at the end of this section to evaluate the students' work. The rubric can also be used by the students as a self-evaluation.

Extensions:

- Research additional non-native plant species in the bosque. Some examples are:
    - Camelthorn *(Alhagi maurorum)*
    - Common cocklebur *(Xanthium strumarium)*
    - Hoary cress *(Lepidium draba)*
    - Mulberry *(Morus alba)*
    - Musk thistle *(Carduus nutans)*
    - Perennial pepperweed *(Lepidium latifolium)*
    - Puncturevine *(Tribulus terrestris)* (aka goat heads)
    - Russian knapweed *(Rhaponticum repens)*
    - Silverleaf nightshade *(Solanum elaeagnifolium)*
    - Tumbleweed *(Salsola tragus)*
- Not all invasive species in New Mexico are plants. Aquatic ecosystems are particularly hard hit by invasive species of animals. For example, Red-eared sliders are often released into the river by well-intentioned

pet owners wanting to give their pet a better life (or just not wanting to care for it anymore). This species is not native to the Rio Grande drainage and poses a threat to the native Big Bend slider not only through direct competition for food and basking sites but also through potential interbreeding and associated impacts on the genetic integrity and adaptations of the native turtles. Similarly, though bullfrogs are native to the eastern US, they have been introduced into western river systems where they have negatively impacted many native species, primarily through predation. Zebra and Quagga mussels, originally from Europe, have also invaded western water systems. They pose a particular threat to New Mexico lakes and reservoirs since they are not yet present in the state but are found in neighboring states and are spread through the actions of humans (i.e., especially on boats brought into New Mexico from states where these species are found). Brown and Rainbow trout, though very popular with anglers, were also introduced to New Mexico and are originally from Europe, Asia, and the west coast of North America.

Research the impact of invasive and exotic animals in New Mexico. Examples include:

- ◦ Zebra and Quagga mussels
  (Dreissena polymorpha and *Dreissena rostriformis)*
- ◦ Northern and Red swamp crayfish
  (Faxonius virilis and *Procambarus clarkii)*
- ◦ Brown trout *(Salmo trutta)*
- ◦ Rainbow trout *(Oncorhynchus mykiss)*
- ◦ Bullfrog *(Lithobates catesbeianus)*
- ◦ Red-eared slider *(Trachemys scripta elegans)*

- Bring in a civics discussion. Government agencies must wrestle with managing their lands. Generally, the public is invited to weigh-in on management plans. This is participatory government. Students can look at what the process would be to implement their management plan. Help students understand that it may take years to actually do the management changes that are proposed; the wheels of government may move slowly.
- Challenge students to think about the Tamarisk leaf beetle, intentionally introduced to control saltcedar (tamarisk). Two exotic species, one is reducing the other. In some areas, the Southwestern Willow Flycatcher has been using saltcedar for its habitat where native riparian trees are absent. *What happens to the Southwestern Willow Flycatcher when saltcedar is reduced?* **(MS.LS2.C; Cause & Effect)**
- --Research how invasive species complicate managing and modeling climate change effects. Look for how your assigned invasive species is expected to fare with climate change. Also consider how

invasive species fit into the mix of predicting climate change effects. *How do models of climate change include invasive species effects? Are there things we, as individuals and communities, can do to mitigate the impacts of invasive species on native ecosystems due to climate change?* **(MS.ESS3.D; HS.ESS3.D)**

NGSS Connections to Invasive Species – Disciplinary Core Ideas

MS.LS2.A Interdependent Relationships in Ecosystems

-In any ecosystem, organisms and populations with similar requirements for food, water, oxygen or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction.

-Similarly, predatory interactions may reduce the number of organisms or eliminate whole populations of organisms. Mutually beneficial interactions, in contrast, may become so interdependent that each organism requires the other for survival. Although the species involved in these competitive, predatory, and mutually beneficial interactions vary across ecosystems, the patterns of interactions of organisms with their environments, both living and nonliving, are shared.

Adding a new species to an ecosystem can create issues with the native species already present. Competition for limited resources can result in the native species not being able to survive as they have previously. New species may not have natural predators as the native species do, may be able to reproduce prolifically, or may have some other feature or behavior that gives them an edge against native species. A predatory species, like bullfrogs, may eat many native animals; bullfrogs have contributed to the decline of native amphibians. If a new organism is added to an ecosystem, how does it interact with species that were there already?

If there are exotic predatory animals in an ecosystem, how might they affect native animals?

MS.LS2.C Ecosystem Dynamics, Functioning and Resilience

-Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations.

-Biodiversity describes the variety of species found in Earth's terrestrial and oceanic ecosystems. The completeness or integrity of an ecosystem's biodiversity is often used as a measure of its health.

Invasive species, whether plants, animals, or even microbes or fungi, can disrupt an ecosystem, negatively affecting populations of native species. Although adding a new, non-native species might increase the species richness (number of species) present in an ecosystem, invasive species are not considered to increase local biodiversity. Their presence can disrupt the biological integrity at a site by competing with native species for limited resources, altering the habitat, directly preying on native species, and more.

How do invasive species disrupt an ecosystem? What kinds of shifts in other species can be seen?
How would invasive species affect the biodiversity of an ecosystem?

MS.ESS3.C Human Impacts on Earth Systems

-Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things.

Humans have introduced exotic species, whether intentionally or accidentally, to ecosystems worldwide, often with devastating effects to local habitats and to native species. Some native species are more susceptible to the effects of invasive species than are others, and thus, the effects on native species vary. Sometimes the negative impact of invasive species can be reversed with human intervention.

How have human activities regarding invasive species impacted habitats or other species (positively and negatively)?

MS.ESS3.D Global Climate Change *Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding human behavior and applying that knowledge wisely in decisions and activities.*

Riparian ecosystems are experiencing dramatic challenges in the face of climate change. Systems already stressed by a changing climate are often more susceptible to invasion by non-native species, which may be favored over native species by the new climatic conditions. Alternatively, the disruption of biological integrity in systems already affected by invasive species may make them more vulnerable to a changing climate. Understanding and addressing this interaction will be essential to managing natural ecosystems in the future.

Research how invasive species complicate managing and modeling climate change effects. Look for how your assigned invasive species is expected to fare with climate change. Also consider how invasive species fit into the mix of predicting climate change effects.

How do models of climate change include invasive species effects? Are there things we, as individuals and communities, can do to mitigate the impacts of invasive species on native ecosystems due to climate change?

HS.LS2.C Ecosystem Dynamics, Functioning and Resilience

-A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability.

-Moreover, anthropogenic changes (induced by human activity) in the environment—including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change—can disrupt an ecosystem and threaten the survival of some species.

Invasive species can disrupt ecosystems by competing with native species over limited resources, by preying on native species, by altering the local habitat, and in other ways. Human-caused introductions of invasive species, whether intentional or accidents, may have devastating impacts on local ecosystems and native species.

When invasive species are introduced by humans, how are ecosystems disrupted? How are native species' survival threatened?

HS.LS4.D Biodiversity and Humans

Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus, sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value.

The introduction of invasive species, whether intentional or accidental, can adversely affect biodiversity and the functioning of ecosystems. Riparian ecosystems are particularly susceptible to these invasions. These changes in biodiversity can directly impact humans by decreasing the availability of natural resources and interrupting natural ecosystem functions upon which humans depend (e.g., flood control, water availability).

How do humans depend on the biodiversity of natural ecosystems?.

HS.ESS3.C Human Impacts on Earth Systems

-The sustainability of human societies and the biodiversity that supports them require responsible management of natural resources.

-Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation.

Humans depend on a variety of natural resources for their survival. Land managers face many challenges in maintaining local biodiversity and thus in maintaining natural resources used by humans. Controlling invasive species is an important task of land managers and often requires creative strategies for success.

In this activity, students are challenged to work on the problem of invasive species at a wildlife refuge—a real issue for natural area managers in New Mexico. The preparation of a management plan for the invasive species the team investigates should address this standard. *What would be involved with restoring habitat in this location—in this example, managing invasive species to ensure native species can thrive in this area? How can scientists and/or engineers help prevent ecosystem degradation by invasive species? How can humans help to sustain the biodiversity of native ecosystems? Think of examples where a reduction in invasive species can help the natural biodiversity in an area.*

HS.ESS3.D Global Climate Change

-Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts.

Through computer simulations and other studies, important discoveries are still being made about how the ocean, atmosphere, and biosphere interact and are modified in response to human activities.

Riparian ecosystems are particularly vulnerable to a changing climate and to the introduction of invasive species.

Research how invasive species effects are included in models predicting climate change effects on ecosystems.

Look for how your assigned invasive species is expected to fare with climate change. Also consider how invasive species fit into the mix of predicting climate change effects. *How do models of climate change include invasive species effects? Are there things we, as individuals and communities, can do to mitigate the impacts of invasive species on native ecosystems due to climate change?*

New Mexico-Specific Science 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 Invasive Species activity.

New Mexico Performance Expectation

HS. *Interdependent Relationships in Ecosystems*

HS-LS2-7 NM. *Using a local issue in your solution, design and analyze the advantages and disadvantages of human activities that support the local population such as reclamation projects, building dams, and habitat restoration.*

HS.LS2.C Ecosystem Dynamics, Functioning and Resilience *A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability. Moreover, anthropogenic changes (induced by human activity) in the environment—including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change—can disrupt an ecosystem and threaten the survival of some species.*

Invasive species can disrupt ecosystems by competing with native species over limited resources, by preying on native species, by altering the local habitat, and in other ways. Human-caused introductions, whether intentional or accidents, may have devastating impacts on local ecosystems and native species. *When invasive species are introduced by humans, how are ecosystems disrupted? How are native species' survival threatened?*

HS.LS4.D Biodiversity and Humans *Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus, sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value.*

The introduction of invasive species, whether intentional or accidental, can adversely affect biodiversity and the functioning of ecosystems. Riparian ecosystems are particularly susceptible to these invasions. These changes in biodiversity can directly impact humans by decreasing the availability of natural resources and interrupting natural ecosystem functions upon which humans depend (e.g., flood control, water availability). In this activity, students are challenged to work on the problem of invasive species at a wildlife refuge—a real issue for natural area managers in New Mexico. *What would be involved with restoring habitat in this location—in this example, managing invasive species to ensure native species can thrive in this area? How do humans depend on the biodiversity of natural ecosystems? How can humans support the biodiversity of native ecosystems? Think of examples where a reduction in invasive species can help the natural biodiversity in an area.*

ETS1.B Developing Possible Solutions

-When evaluating solutions, it is important to take into account a range of constraints including cost, safety, reliability and aesthetics and to consider social, cultural and environmental impacts.

In writing a management plan for addressing invasive species at a wildlife refuge, students should consider a range of options and the effects of those options. This is what land managers need to do as they work through issues concerning threats to our public lands. Be sure to include consideration of social and cultural impacts; these are particularly meaningful here in New Mexico but may easily be overlooked when focusing on ecological and environmental impacts.

CCCs Stability and Change

SEPs Constructing Explanations and Designing Solutions

Connections to Nature of Science

Science is a Way of Knowing

-Science is both a body of knowledge that represents a current understanding of natural systems and the processes used to refine, elaborate, revise and extend this knowledge.

-Science is a unique way of knowing and there are other ways of knowing.

-Science distinguishes itself from other ways of knowing through use of empirical standards, logical arguments, and skeptical view.

-Science knowledge has a history that includes the refinement of, and changes to, theories, ideas and beliefs over time.

New Mexico Performance Expectation

HS.Science and Society

HS-SS-2 NM. *Construct an argument using claims, scientific evidence, and reasoning that helps decision makers with a New Mexico challenge or opportunity as it relates to science.*

ETS1.A Defining and Delimiting Engineering Problems

-Criteria and constraints also include satisfying any requirements set by society such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them.

-Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities.

In designing a management plan to address invasive species, engineering solutions may be part of the plan. In considering those solutions, students need to consider issues associated with maintaining a healthy society. *For example, is one of the recommendations applying herbicides or pesticides? How would they be applied? What effects can be expected on target plants, non-target plants, and the ecosystem in the long-term or in downstream areas?* Can the application procedure be improved and/or risks mitigated with proper training, timing, and/or hand preparation work? Students can construct an argument for their suggested alternatives.

How would management strategies affect global systems at the local level, such as the local water supply? Would application of herbicides/pesticides get into local water sources, with further, downstream effects? Would any of the proposed management strategies affect food supplies (such as alfalfa production)? Challenge students to consider effects beyond the immediate area of the refuge.

ETS1.B Developing Possible Solutions *When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts.*

In writing a management plan for addressing invasive species at a wildlife refuge, students should consider a range of options and the effects of those options. This is what land managers need to do as they work through issues concerning threats to our public lands. Be sure to include consideration of social and cultural impacts, (e.g., input and/or advice from Native communities) as these are particularly meaningful here in New Mexico but may easily be overlooked when focusing on ecological and environmental impacts. Make an argument for your recommendation; state any risks and how those can be mitigated. Emphasize how your preferred approach is the best plan. Use arguments such as: the most cost effective, safe, aesthetically pleasing, socially and culturally sensitive, etc. Identify specific bosque species affected such as Species of Greatest Conservation Need (SGCN.)

CCCs: Cause and Effect

SEP: Engaging in Argument from Evidence

Connections to Nature of Science

Scientific Knowledge is Open to Revision in Light of New Evidence

-Most scientific knowledge is quite durable but is, in principle, subject to change based on new evidence and/or reinterpretation of existing evidence.

-Scientific argumentation is a mode of logical discourse used to clarify the strength of relationships between ideas and evidence that may result in revision of an explanation.

Science Addresses Questions about the Natural and Material World

-Science and technology may raise ethical issues for which science, by itself, does not provide answers and solutions.

-Science knowledge indicates what can happen in natural systems— not what should happen. The latter involves ethics, values, and human decisions about the use of knowledge

Invasive Species

Introduction

There are aliens in New Mexico! No, not UFOs, but alien, non-native plants. Non-native plants that cause environmental harm are often called "invasive species." These species, like saltcedar (tamarisk), are threatening the health of the bosque ecosystem by taking over from the species that have lived there for thousands of years.

Here is the scenario: The state legislature of New Mexico has established a new wildlife refuge along a five-mile (8 kilometer) stretch of the Middle Rio Grande. According to the legislation, the mission of the refuge is to preserve the beauty of the bosque and to provide habitat for native bosque plants and animals, and for the enjoyment of all New Mexicans. What should be done about the invasive plants?

Task

You and a partner have been hired by the refuge manager as invasive plant consultants. You will work together as a team to become experts on a particular invasive or noxious species. Your team will then determine a management plan for this species and present it to the class during a "public hearing." It will be your job to learn more about this species and about ways to manage it.

Process

Step 1. Your teacher will assign your team an invasive or noxious species to research. As a team, you will locate websites or webpages about your species, documenting your sources as you go.

Step 2. Using these sources, you will prepare a species profile.

Step 3. Write a management plan.

Step 4. Present your management plan to the class. You may do a computer presentation or a poster with appropriate drawings and illustrations.

Step 5. Evaluate your team's work.

Step 1: Website Identification - Documentation of Research

Find at least three websites that have descriptions of the invasive species you have been assigned. Fill out the information on the documentation handout for each website you find that contains information useful to your species profile and/or management plan. You may add additional websites if you find more than three that seem especially useful.

Begin by looking up the common name and/or the scientific name of the species. You will have to decide which sites best suit your needs. Sites with addresses that end in .gov (government) or .edu (education) tend to have more credible information than ones that end in .com or .net. Ultimately, it is up to you to decide which sites provide the best information for your purposes.

Step 1: Website Identification - Documentation of Research (short version)

Website 1
URL (address):
Who sponsors or hosts this web page?
Who is the intended audience?
One thing you learned about your invasive species is:

Website 2
URL (address):
Who sponsors or hosts this web page?
Who is the intended audience?
One thing you learned about your invasive species is:

Website 3
URL (address):
Who sponsors or hosts this web page?
Who is the intended audience?
One thing you learned about your invasive species is:

Step 1: Website Identification - Documentation of Research using the Council of Science Editors (CSE) style

Website 1
Author's name (last name, first initials; if known)
Date of publication or last revision
Title of website
Place of publication (City [State initials]) and publisher name/organization
Title of web page/document; publication date
Update and/or access date
[updated year, abbreviated month day; cited year, abbreviated month day]
URL
Information addressing your questions:

Website 2
Author's name (last name, first initials; if known)
Date of publication or last revision
Title of website
Place of publication (City [State initials]) and publisher name/organization
Title of web page/document; publication date
Update and/or access date
[updated year, abbreviated month day; cited year, abbreviated month day]
URL
Information addressing your questions:

Website 3
Author's name (last name, first initials; if known)
Date of publication or last revision
Title of website
Place of publication (City [State initials]) and publisher name/organization
Title of web page/document; publication date
Update and/or access date
[updated year, abbreviated month day; cited year, abbreviated month day]
URL
Information addressing your questions:

Using the above information, the format for including a CSE style citation in a written document is as follows:

> Author last name, first/middle initials. (year published). Title of website, [Internet]. Publication city(state): Publisher/Organization. Title of web page [updated year abbreviated month day; cited year abbreviated month day]. Available from: URL

Step 2: Species Profile

Using the websites you have identified, complete a profile of your species. You should incorporate information from all of the websites you documented.

Common name:

Scientific name:

Physical description (including size, leaf description, flower description, color, etc.):

How does it propagate/reproduce?

Distribution (where is it found?):

Effect on natural areas and/or native species:

Three methods for management:

List three terms (words you didn't know) and definitions:

Step 3: Management Plan

Now that you have researched your non-native species, it is time to make your management recommendation to the refuge manager. Your management plan should be two to three typed pages in length.

Your management plan needs to include the following elements: statement of the problem, species profile, description of various alternative management strategies, final recommendation for species management, definition of terms, and a webography (full URL of websites used, plus sponsors, audience, and short notes on information gained there). Use this outline to help you prepare your management plan.

I. Statement of the problem (two or three sentences about why this species is an invasive species).

II. Species profile (one or two paragraphs describing where this species is found in the bosque, what it looks like, and how it affects the bosque ecosystem. Identify specific bosque species affected such as Species of Greatest Conservation Need [SGCN]).

III. Description of various alternative management strategies and advantages and disadvantages of the alternatives (one paragraph for each alternative). One of the alternatives must be a do-nothing alternative.

   A. Description; advantages and disadvantages

   B. Description; advantages and disadvantages

   C. Do nothing; advantages and disadvantages

IV. Your recommendation for managing the invasive species. Use the format of Claim, Evidence, Reasoning. Make an argument for your recommendation; state any risks and how those can be mitigated. Emphasize how your preferred approach is the best plan. Use arguments such as: the most cost effective, safe, aesthetically pleasing, socially and culturally sensitive, etc.

V. Unfamiliar terms and definitions.

VI. Webography of web sites you accessed for the information included in your plan. Use CSE citation format, as appropriate for the student's level.

Step 4: Presentation.

Present your management plan to the class using a computer presentation or poster format.

Step 5: Evaluate this unit with the rubric

(see separate handout)

Invasive Species
Evaluation Rubric
Name ___________________________

Component	Beginning Level	Developing Level	Advanced Level	Student Score	Teacher Score
Oryx Research	0 points. Didn't follow directions. Answered fewer than half of the questions correctly.	3 points. Followed directions. Answered more than half of the questions correctly	6 points. Followed directions. Answered eight or more questions correctly.		
Website Identification	0 points. Found fewer than three websites. Did not identify sponsor & audience for each site. Did not answer question about particular invasive species.	3 points. Found three websites. Identified some sponsors & audiences. Showed basic understanding of particular invasive species (answers were repetitive or simplistic).	6 points. Found three or more websites. Identified sponsor & audience for each. Showed strong understanding of particular invasive species.		
Species Profile	0 points. Completed fewer than half the components of the profile.	4 points. Completed three-fourths of the components of the profile.	8 points. Completed all components of the profile.		
Management Plan	0 points. Addressed fewer than half of the elements of the plan. Plan is messy, illegible, and/or less than one page with numerous grammatical and/or spelling errors.	6 points. Addressed most elements of the plan. Plan is neatly hand-written and/or less than one page, with few grammatical and/or spelling errors.	12 points. Addressed all elements of the plan. Plan is typed, one or two pages, with no grammatical or spelling errors.		
Presentation	0 points. Presentation is incomplete using paraphrased words and/or no pictures. Presentation shows little understanding about invasive species in general and/or particular species.	6 points. Presentation includes essential information with some elaboration. Presentation shows some understanding about invasive species in general and/or particular species.	12 points. Presentation is complete with original words and pictures. Presentation shows understanding about invasive species in general and about particular invasive species.		
Teamwork	0 points. Teammates often "did their own thing"; were not able to work together to accomplish task; had difficulty getting along with each other.	3 points. Teammates were mostly able to participate appropriately; usually came prepared and accomplished the task; avoided most conflicts and/or were able to resolve any that occurred.	6 points. Team members contributed fairly and squarely to all aspects of the project; always came prepared and accomplished the task; worked well cooperatively.		
Total Score				50	50

46. Energy in Bosque Ecosystems

Description: Students follow the path of energy through the bosque ecosystem. In either a small group presentation or as a poster, teams of students use appropriate vocabulary to illustrate energy gained and lost through a short food chain, from a plant to an herbivore to a carnivore.

Objective: Students will be able to state sources of energy in ecosystems, show a path of energy through a short energy food chain, and describe at least 3 types of energy that are gained and lost by plants and/or animals. This activity is centered on the bosque and river ecosystems of the Southwestern US.

Materials:

- Selected "Food Chain Sets" cut apart; distribute one food chain per team
- Animal and plant cards from "Who Lives Where?" and "Who Grows Where?" activities in this *Guide*. Go here to find corresponding plants and animals for each team's assigned "Food Chain Set." Include both the picture and its description. Note you may need several copies of some card sets, such as algae. Be sure to count the number of cards needed for all of your chosen food chain sets.
- Algae card - copy from this activity
- Markers
- Tape or glue
- Scissors
- Poster paper (for option B)

46. Energy in Bosque Ecosystems

Grades: 4-8

Time: 45 - 90 minutes

Subjects: science, environmental education

Standards: see end of activity

Terms: *carnivore, primary and secondary consumers, decomposer, detritivores, dissipate, food chain, food web, glucose, herbivore, matter, photosynthesis, predator/prey, producer; energy terms: chemical potential energy, electrical energy, heat energy, kinetic energy, light energy, sound energy*

New Mexico STEM Ready! / Next Generation Science Standards

NGSS DCIs and Performance Expectations

5.LS1.C Organization for Matter & Energy Flow in Organisms
5.LS2.A Interdependent Relationships in Ecosystems
5.LS2.B Cycles of Matter & Energy Transfer in Ecosystems
5.PS3.D Energy in Chemical Processes & Everyday Life
MS.LS1.C Organization for Matter & Energy Flow in Organisms
MS.LS2.B Cycles of Matter and Energy Transfer in Ecosystems
MS.PS3.D Energy in Chemical Processes & Everyday Life

NGSS CCCs

Systems and System Models; Energy and Matter: Flows, Cycles & Conservation

NGSS SEPs

Developing & Using Models; Constructing Explanations & Designing Solutions; Engaging in Argument from Evidence

Option A

- Acting out an energy food chain—Paper strips/index cards—students will write types of energy on index cards

Option B

- Drawing out an energy food chain

Background: Energy as a unifying concept is addressed in a range of fields of science including physical science and biological science. In the biological sciences, foundational concepts include understanding the sources of energy in an ecosystem, and how each organism gets the energy that it needs to survive and thrive. This activity helps students both understand the types of energy in ecosystems, and also adaptations and interrelationships of organisms in their local bosque ecosystem. *Bosque* is the Spanish word for "forest" or "woods" but it is generally used in New Mexico to refer to the cottonwood forest along rivers in the region. Bosque habitat is found along rivers throughout the Southwest, and the same ecological processes occur anywhere cottonwoods are found in the Southwest and can be illustrated in both aquatic and terrestrial parts of the ecosystem.

Most students, by the time they reach upper elementary and middle school, can tell you that plants do something unique called **photosynthesis**. But in order to fully put that word into the context of the energy needs of an entire ecosystem, it takes some focused vocabulary and tracing of that energy in different parts of the ecosystem.

What is the source of energy for plants growing in the bosque (and across most of the Earth)? ***Light Energy*** (LE) from the sun. Plants are able to take carbon dioxide and water and through the process of photosynthesis— using their green chlorophyll pigment and using *Light Energy* from the sun, run complex reactions—to produce sugars in the form of glucose. The plants also produce oxygen as a waste product—which is something that animals make vital use of in respiration. In this way, plants make their own food and food that is available to other organisms; they are known as **producers**.

Glucose sugar is, for the plant, a source of ***Chemical Potential Energy*** (CPE). Glucose sugar is a stable substance that can be used later for growing stems, leaves, roots, flowers, and seeds-- the normal processes of a plant's life—all run by the glucose energy produced by photosynthesis. CPE—Glucose, is a compound with a chemical structure that can be stable for extended periods, later providing the energy for plant growth and other needs. This is the chemical energy, stored in a way to provide potential energy (available for later use) for the organism—*Chemical Potential Energy*.

Other types of energy can be associated with plants: there might be ***Sound Energy*** (SE) as when the wind blows and leaves rustle; ***Kinetic Energy*** (KE) as when plants grow or move with wind or when sunflowers move their flower head to follow the sun. Some plants actually produce ***Heat Energy*** (HE), intensifying their flower scent for pollinators. These are some of the ways that small amounts of energy leave the plant, beyond the *Chemical Potential Energy* described above.

Sometimes, an animal, called an **herbivore**, will come along and eat a plant. *Why does an animal do this?* To get energy for itself. The energy the herbivore needs is the glucose sugar the plant has produced—this is the *Chemical Potential Energy* stored in the plant cells, that the animal is able to access. Through digestion, the sugars are broken down and provide energy for the animal's processes of daily life—growing cells, digesting, breathing, moving, reproducing, etc. Plant-eating animals are also known as **primary consumers**.

Other types of energy that the animal creates are: *Kinetic Energy,* as the animal moves; *Sound Energy* made through calls or interactive movements; *Heat Energy* generated through metabolism and movement; *Electrical Energy* within the working brain and nervous system. (See ***Terms***.)

Each of these other types of animal energy go off into the world, and are not really useable by other living organisms: the heat **dissipates**, scattering in the air, the sound, as well as the kinetic movement dissipates. Energy is never lost—it can be accounted for, but it does not necessarily help other living parts of the ecosystem. In this way you can start to see that energy is not cycled through the ecosystem—it is on a one-way path from the sun through organisms as CPE, but is lost from potential usefulness to others, bit by bit, by various organisms in the ecosystem (see Energy Chain diagram).

Finally, a **carnivore** may eat an herbivore. When it eats the herbivore, it is accessing Chemical Potential Energy! The herbivore has CPE in the form of glucose in its body—in the muscle and organs that it built as it ate and digested its food. So the carnivore is utilizing the CPE that the plant produced to grow itself, that the herbivore ate to grow itself and now the carnivore eats to grow itself. Because they eat the primary consumers (herbivores), carnivores are called **secondary consumers**.

Again, there are many other forms of energy that the carnivore may produce during its daily activities: *Kinetic Energy* as it moves; *Heat Energy* as it keeps its body temperature constant; *Electrical Energy* as its brain and nervous system work; *Sound Energy* as it communicates with others, or, if a bird, as its feathers cut through the air.

The important point for your students to understand is that *Chemical Potential Energy* is the main source of energy for the ecosystem. CPE, in the form of glucose, is produced by plants for their own growth. Herbivores eat plants, gaining the source of energy for their own daily life and growth—CPE—glucose sugars. And finally, a carnivore may eat an herbivore, gaining the *Chemical Potential Energy* that it needs to survive and thrive, also in the form of glucose sugars.

Contrast matter to energy

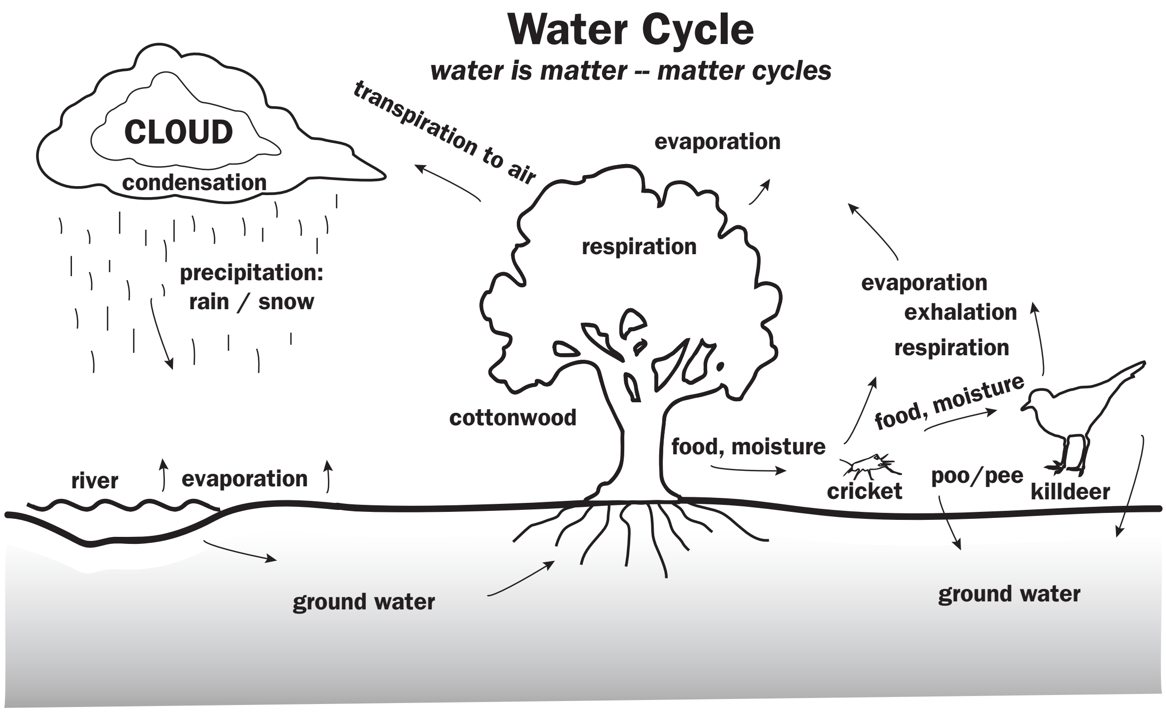
Energy is on a one-way path—it cannot be cycled back like matter. As *Chemical Potential Energy* it travels through the ecosystem as a critical energy source, but once used for heating, moving, sound, and brain work, it is never available again. Only the *Chemical Potential Energy* contained in the organism that becomes food for something else (such as muscle and organs, or poo!) is passed along and useful for another organism's survival—fulfilling their energy needs for living (see Ecosystem Energy Chain diagram).

Matter, on the other hand, is cycled. For example, carbon is used by organisms, and after death, the carbon may be freed to be taken up by another organism. Water is cycled, used by an organism, eliminated, and returned back to the ecosystem and used again. The same is true for nitrogen and other compounds of matter; they are important and used over and over (see Water Cycle diagram).

Also see "Rio Grande Water Cycle" activity in this *Guide.*

Cottonwood leaf
Photograph by Letitia Morris

Compare the cycling of matter such as this water cycle
to the one-way path of energy in an ecosystem.

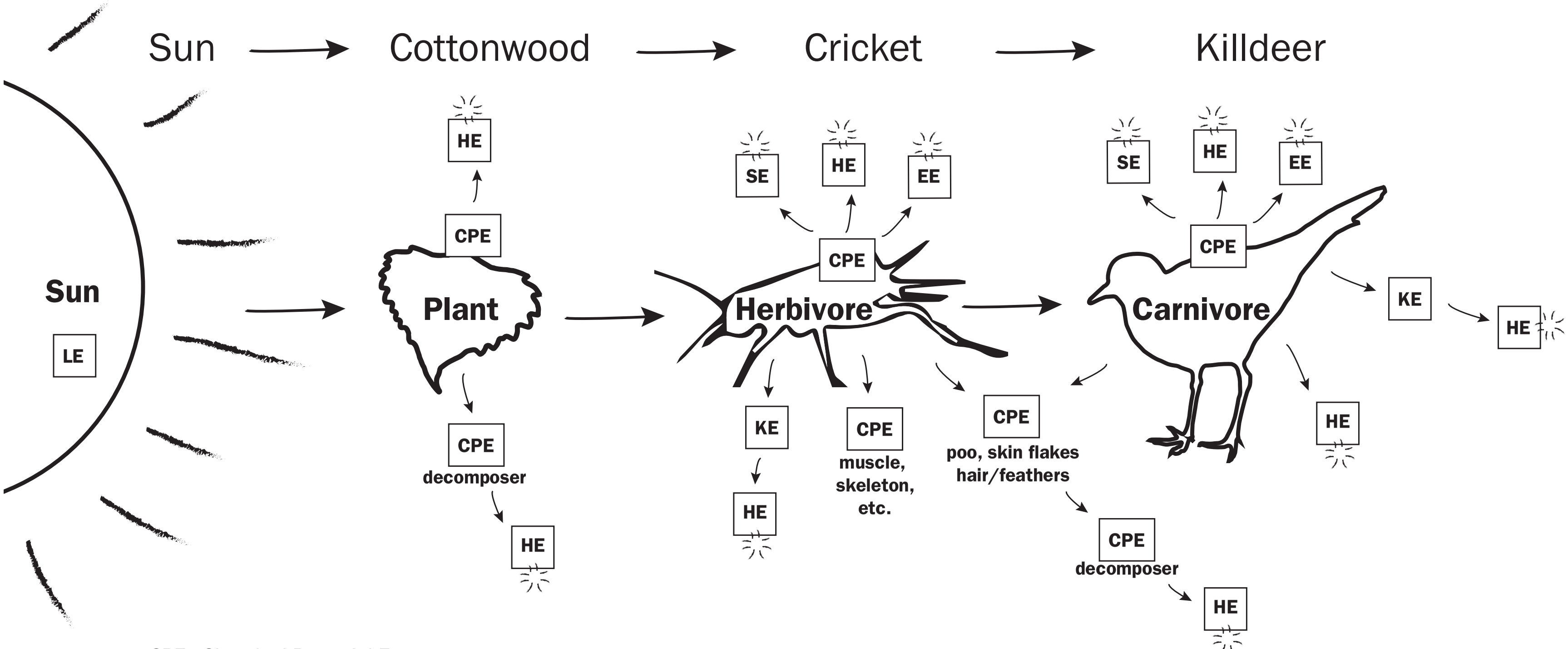


Misconceptions:

Where do plants get their food? —Many students think that food comes through roots, from soil. Even though you can see "Plant Food" sold in gardening supply stores—those are just plant nutrients—*plants make their own food* from sunlight, carbon dioxide (CO_2), and water (H_2O) through the <u>process</u> of photosynthesis. This is similar to humans taking vitamins; vitamins provide important nutrients, but they are not food. Humans cannot live on vitamins alone, but do need vitamins to survive.

Should you include the sun in a "food" chain? No—It is energy. Include in an energy chain, but not a matter/food chain! This activity does focus on energy transfers, and is focusing on energy chains.

Ecosystem Energy Chain



CPE - Chemical Potential Energy
EE - Electrical Energy
HE - Heat Energy
KE - Kinetic Energy
LE - Light Energy
SE - Sound Energy
- Energy leaving the system, no longer useable by organisms in the ecosystem

Terms:[1]

Energy: a quantity of how much change can happen in a system. Energy is conserved—not lost or destroyed; all energy can be measured and accounted for even through many changes in the natural world. Another definition of energy is: the ability to do work, to make things happen. [This activity illustrates the types of energy, and not the quantity of energy—which would be measured in joules or calories (among other units used in various fields).]

Matter: has mass and takes-up space. The molecules of matter are the material that make up all the things around us: rocks, plants and animals, the oxygen in the air, the water on Earth, and so much more.

Types of Energy

Energy of Position—Energy due to the relative positions of matter

Chemical Potential Energy (CPE)—is a result of the structural arrangement of atoms and molecules. When bonds are broken and new bonds form, atoms rearrange. This rearrangement changes the relative positions of atoms and, in turn, changes the amount of CPE present.

Energy of Motion—Energy due to the motion of matter

Kinetic Energy (KE)—is a result of an individual object's motion (e.g., a hockey puck sliding on ice, a car speeding along a road, a particle moving through space). Objects with more mass and those moving at higher velocities have more KE.

Heat Energy (HE)—is a result of the random motion of all the atoms and molecules that make up an object. Objects with more mass and at a higher temperature have more HE. The kind of matter and its phase (e.g., solid, liquid, gas) affect the amount of HE produced.

Light Energy (LE)—is a result of the coordinated motion of photons that are emitted when electrons, protons, and other charged particles accelerate. High frequency colors (e.g., blue) transmit more LE than low frequency colors.

Sound Energy (SE)—is a result of atoms and molecules moving in concert to form temporary regions of compression and expansion in a medium (e.g., air or water). Louder sounds and higher pitched sounds transmit more SE compared to whispers and deep pitched sounds.

Electrical Energy (EE)—is a result of charged particles moving through a conductor (e.g., current from electrons moving through a wire). The more current that flows and the longer the period of time it flows, the more EE is present.

Procedure:

- As a class, brainstorm, *What does the word "energy" make you think of?*

  List ideas on the board. Examples: moving, warming, growing, sound, light, heat, electrical, collisions.

  This activity will focus on energy in ecosystems, leaving other energy discussions for other times.

Option A: **Acting out an energy food chain**

- Choose the correct number of "Food Chain Sets" for your class. Each set needs 3 students; a few two and four person sets are available if needed.

- Hand out animal and plant cards, one per person; hand both the image and the text card to that person.

  You could assign teams to the sets above. Or, depending on your group's dynamics, you could use a more random group assembly—hand out cards, give a few moments to read their cards, then stand and find others that should be in a short food chain with them, finding a plant, an herbivore, and a carnivore to form a food chain set. Each text card lists these connections.

- Their challenge is to first make a simple food chain. Each group must include a plant, a plant eater (herbivore), and an eater of plant eater (carnivore).

  They must consider the path of energy through this food chain and show to the whole group in a demonstration or skit-like presentation:

  What species are in their food chain?

  Identify the energy types and path in your food chain/energy transfers.

  They should look at the list of optional energy types and make index cards of those types (e.g., several CPE cards for each team, one LE card for sunlight to plant, a few SE, HE, KE, and EE for each team).

- Their challenge is to tell the class:

  Where does the energy come from in this food chain?
  Show examples of energy types moving through the food chain.

- Use these terms as well, when/where appropriate:

  Producer   Predator/Prey or Herbivore/Carnivore

  Consumer   Detritivores/Decomposers

- Optional—during class presentations, have other teams help out in adding additional energy that would be a part of that food chain. And, adding other species that might connect with the food chain being presented. You may see some food webs appearing! Food webs have multiple interactions among organisms in an ecosystem. Research shows that students need to work at making the leap from individual food chains to food webs. This may be a way to make the leap to understanding these complexities of dependencies.[2]

Option B

Drawing an energy chain

Introduce the activity as in Option A above.

Review types of energy listed in the terms section. List each energy type on the board.

Do one example for the class. Write name of one "Food Chain Set" on board and label energy types; draw in arrows for direction of movement of energy.

What do arrows in an energy food chain represent? Follow the energy from plant to eater of plant…X goes into the mouth of Y—the CPE/energy of the plant goes into the mouth of the herbivore—the arrow goes from the plant to the eater of the plant. Say in words what is meant by the arrow direction shown.

Distribute one "Food Chain Set" –one plant, one herbivore, and one carnivore—to each team of three students.

A team is challenged to make a poster showing their assigned short food chain and the energy involved in the chain.

Have copies of animal and plant cards from "Who Lives Where?" and "Who Grows Where?" activities--the corresponding plant and animals for each team's assigned "Food Chain Set." Include both the picture and its description. Note, you may need several copies of some card sets, such as cottonwoods. Be sure to count the number of cards needed for all of your chosen sets.

Each team will show on their poster:

- What species they have in their food chain
- Identify the energy types and path in that food chain—the energy transfers, both in and out (see diagram Energy Chain).

The students should look at the list of optional energy types and label their poster with the following where they occur: CPE LE, SE, HE, KE, EE.

- Use arrows to show the direction of energy movement.
- Label your food chain with these terms, when/where appropriate:

Producer Predator/Prey or Herbivore/Carnivore

Consumer Detritivores/Decomposers

- Their challenge is: To tell the whole class

Where does the energy come from in your food chain?

All energy comes from the Sun.

Show examples of energy types moving through the food chain.

Have the students do a class presentation and describe the energy flow that they have illustrated through the food chain.

Energy in Bosque Ecosystems Discussion Questions

What is the major source of energy in ecosystems? The sun with light energy.

What do we need plants for?

- Food. Even if you think of yourself as primarily a carnivore, your energy has ultimately come from plants. Plants produce CPE, herbivores eat plants, carnivores eat herbivores. All organisms are needed.
- Oxygen! Earth has an oxygen-rich atmosphere because plants give off oxygen during photosynthesis.

Where do plants get their food? Through photosynthesis; with carbon dioxide and water, and energy from sunlight, they produce glucose—food for their own growth. [It is a misconception to think that food comes through roots, from soil.]

What do plants need to live, in general?

Water, sunlight, nutrients, carbon dioxide in the air.

What do animals need to survive?

Water, food (CPE!), oxygen in the air.

What would happen if all _____________ *were gone from this ecosystem?*

> *Predators (carnivore; secondary consumer)* Predators eat animals and keep the ecosystem from being over-populated by herbivores.
>
> *Herbivores? (primary consumers)* If there were no herbivores, there would be no food for carnivores and plants might take over.
>
> *Plants? (producers)* The ecosystem depends on plants to produce chemical potential energy that is eaten by other organisms—No plants, no plant eaters, no carnivores.
>
> *Any one kind/species of organism?* Once you look closely at food webs in an ecosystem, you see that the loss of one species often affects many other species. Remove an insect species-- maybe the plant it pollinates fails to produce seed; the animal that eats the insect and the animal that eats the seed decline.

What does your energy food chain help you understand about the ecosystem?

The Sun provides energy for plants, plants provide energy for herbivores, and herbivores provide energy for carnivores.

What doesn't it help with?

It does not show the cycling of matter, only the energy part of a food chain.

Assessment:

The final poster or presentation students create will need to include the following: state the source of energy in ecosystems, show the path of energy through a short energy food chain, and describe at least three types of energy that are gained and lost by plants and/or animals in their food chain.

Extensions:

- Post the food chain posters on the wall. Use yarn to make more connections between the plants and animals across posters—creating an energy-food web.
- Use the decomposer card to add to their energy chain. You could also research other types of decomposers. Write a description of how the decomposer fits into the energy chain—what eats them, and what do they need to survive?
- The base of the food chain in the bosque are plants on land and algae in the water—that make their own food from sunlight. But, there is a different source of energy forming the base of the food chain in deep sea vents-- chemosynthesizing organisms; they get their energy from "black smokers" --volcanic gases emerging at the bottom of the ocean—creating an energy source for an ecosystem that is unrelated to Light Energy from the sun.[3] Have students research this process to contrast with the bosque/terrestrial system.

Resources/References

[1] *Making Sense of Science: Energy for Teachers of Grades 6-8*. Kirsten R. Daehler, Jennifer Folsom, Mayumi Shinohara. WestEd. NSTA Press. 2011.

[2] *Uncovering Student Ideas in Life Science, 25 New Formative Assessment Probes. Vol.1.* Page Keeley. NSTA Press. 2011. (p. 106 must make connections between food chains to get to understanding of food webs.)

[3] *Ecology: Concepts and Applications*, Manuel C. Molles, Jr. WCB McGraw-Hill. 1999.

Written and edited by Letitia Morris, Becky Bixby, Ph.D. and Laurel Ladwig.

Three-Step Food Chain Sets for the Bosque Education Guide

Algae to Caddisfly larvae to American Dipper
Algae to Mayfly larvae to Northern leopard frog
Algae to Mayfly larvae to Rio Grande cutthroat trout
Algae to Mayfly to Southwestern Willow Flycatcher
Algae to Mayfly larvae to Western chorus frog
Algae to Mosquito to Little brown bat
Algae to Mosquito larvae to Red shiner
Algae to Mosquito larvae to Western painted turtle
Algae to Rio Grande silvery minnow to Garter snake
Algae to Rio Grande silvery minnow to Great Blue Heron
Algae to Rio Grande silvery minnow to Belted Kingfisher
Cattail to Canada geese to Coyote
Cottonwood to Cricket to Killdeer
Cottonwood to Cricket to New Mexico whiptail
Cottonwood to Cicada to Greater Roadrunner
Cottonwood to Cricket to Sandhill Crane
Cottonwood to Isopod (Pillbug or Sowbug) to Harvester ants
Cottonwood to Leaf-roller caterpillar to Yellow-billed Cuckoo
Coyote willow to Beaver to Coyote
Giant sacaton to Meadow jumping mouse to Great Horned Owl
Saltgrass to Desert cottontail to Coyote
Saltgrass to White-footed mouse to Bullsnake
Saltgrass to White-footed mouse to Great Horned Owl
Sedge to Mallard duck to Coyote
Spectacle pod (Mustard) to Harvester ants to New Mexico whiptail lizard
Sunflower (roots) to Botta pocket gopher to Coyote
Wolfberry to Summer tanager to Coopers Hawk

Four-Step Food Chain Sets for the Bosque Education Guide

Algae to Mayfly larvae to Northern leopard frog to Spiny softshell turtle
Algae to Mayfly larvae to Rio Grande cutthroat trout to Bald Eagle
Algae to Rio Grande silvery minnow to Garter snake to Greater Roadrunner
Cottonwood to Cricket to New Mexico whiptail to Greater Roadrunner
Cottonwood to Cricket to New Mexico whiptail to Bull snake

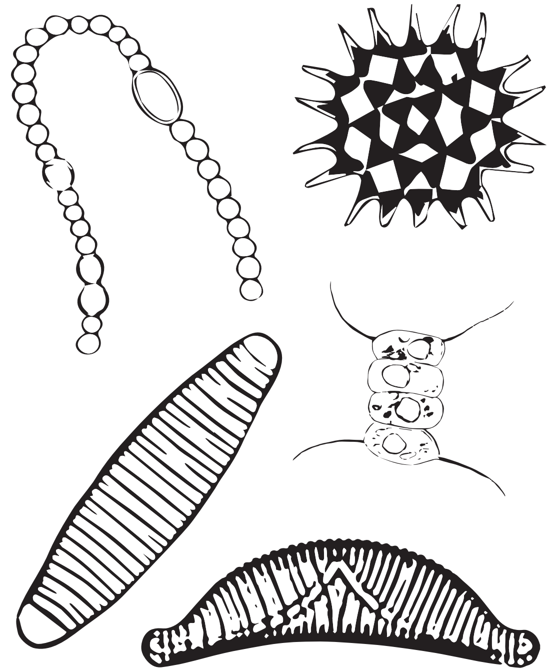
Two-Step Food Chain Sets for the Bosque Education Guide

Cattail to Elk
One-seed juniper to Bear
Prickly pear to Coyote
Screwbean mesquite to Coyote

We are microscopic organisms that live in the Rio Grande or damp sunny places. Some of us live alone; some connect like strands of beads, or stars, or just hang out together. Some of us can "swim" while others just go with the flow. We make our own food from sunlight using our green, blue-green, or golden pigment in our cells. Our growth depends on the amount of light and nutrients available. We take in carbon dioxide and make sugars for our food, like land plants. Oxygen is released by this process. Together with ocean-living relatives, we produce 70-80% of Earth's atmosphere's oxygen! Some of us have cell walls made of glass; the glass pattern of each species is unique. Some of us can create usable nitrogen from the air, supplementing important nutrients for our growth. We are eaten by caddisfly, mayfly, and mosquito larvae and Rio Grande Silvery Minnows among many other animals.

River Algae

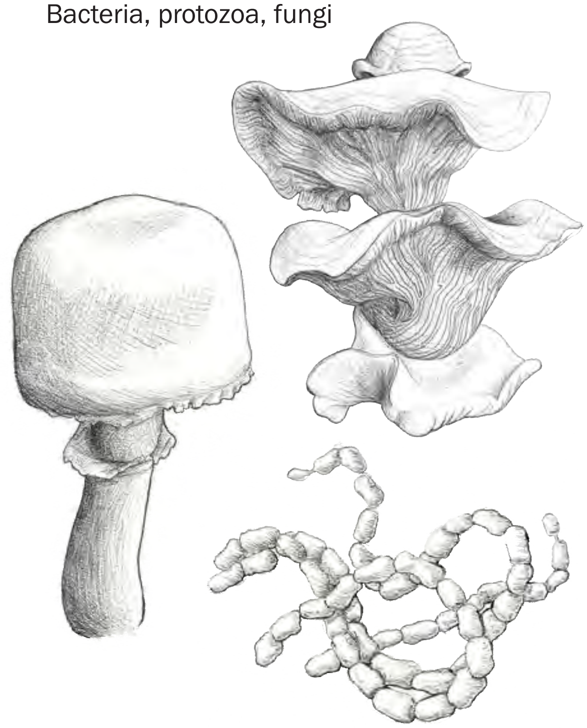
Anabaena, Pediastrum, Scenedesmus, Epithemia, Diatoma



We are nature's recyclers. Any place there is natural waste to break down, we help out. We are small organisms that find the energy and matter we need to grow from the remains of plants and animals. A cricket or isopod will chew fallen cottonwood leaves and then we get to work on the small particles. We break down dead animals, too. Underground, some of us grow slender filaments called hyphae (HI-fee) where we produce enzymes (EN-zimes) to digest material around us, then absorb the nutritious results. We grow better in moist soil. Above ground, you might see our fruiting bodies, which include mushrooms and woody structures called conks. Others of us are microscopic, so you would never know we are there, but we are always at work. A side effect of our diet is that by breaking down this material we leave tiny vital nutrients needed by living plants and algae. Without our work dead things would pile-up everywhere! Imagine that!

Decomposers

Bacteria, protozoa, fungi



NGSS CONNECTIONS TO ENERGY IN BOSQUE ECOSYSTEMS - DISCIPLINARY CORE IDEAS

5.LS1.C Organization for Matter and Energy Flow in Organisms

Food provided animals with the materials they need for body repair, and growth and the energy they need to maintain body warmth and for motion. Plants acquire material for growth chiefly from air, water.

• How do organisms obtain and use the matter and energy they need to live and grow?

PE: 5-LS1-1 *Support an argument that plants get the materials they need for growth chiefly from air and water.*

CCC*:* Energy and Matter: Flows, Cycles and Conservation *Matter is transported into, out of and within systems.*

***SEP:* Engaging in Argument from Evidence** *Support an argument with evidence, data or a model.*

PE: 5-PS3-1 *Use models to describe that energy in animals' food (used for body repair, growth, and motion and to maintain body warmth) was once energy from the sun. [Examples of models could include diagrams and flow charts.]*

CCC: Energy and Matter: Flows, Cycles and Conservation *Energy can be transferred in various ways and between objects.*

SEP: Developing and Using Models *Use models to describe phenomena.*

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 their 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.

• How do organisms interact with the living and nonliving environments to obtain matter and energy?

PE: 5-LS2-1 *Develop a model to describe the movement of matter among plants, animals, decomposers, and the environment. [Clarification statement: Emphasis is on the idea that matter that is not food (air, water, decomposed materials in soil) is changed by plants into matter that is food. Examples of systems could include organisms, ecosystems, and Earth.] [Does not include molecular explanations.]*

CCC: Systems and System Models *A system can be described in terms of its components and their interactions.*

SEP: Developing and Using Models *Develop a model to describe phenomena.*

5.LS2.B Cycles of Matter and Energy Transfer in Ecosystems

Matter cycles between the air and soil and among organisms as they live and die. Organisms obtain gases and water from the environment and release waste matter (gas, liquid, or solid) back into the environment.

• How do matter and energy move through an ecosystem?

This activity focuses on the energy moving through the ecosystem and less on the matter moving through. But it is not hard to look at matter as well. It is also a confusing concept where students need to tease apart the ideas about chemical potential energy (CPE) that is stored in the form of glucose and has mass—it is the "stuff" of the food we all eat—but through cellular respiration CPE is released, providing the energy all life uses to move, build cells and grow. The Rio Grande Bosque Water Cycle activity in this *Guide* demonstrates a matter cycle.

PE: 5-LS2-1 *Develop a model to describe the movement of matter among plants, animals, decomposers, and the environment. [Clarification statement: Emphasis is on the idea that matter that is not food (air, water, decomposed materials in soil) is changed by plants into matter that is food. Examples of systems could include organisms, ecosystems, and Earth.] [Does not include molecular explanations.]*

CCC: Systems and System Models *A system can be described in terms of its components and their interactions.*

SEP: Developing and Using Models *Develop a model to describe phenomena.*

5.PS3.D Energy in Chemical Processes and Everyday Life

The energy released from digesting food was once energy from the sun that was captured by plants in the chemical process that forms plant matter (from air and water). 5-PS3-1

• How do food and fuel provide energy?

PE: 5-PS3-1 *Use models to describe that energy in animals food (used for body repair, growth, and motion and to maintain body warmth) was once energy from the sun. [Examples of models could include diagrams and flow charts.]*

CCC: Energy and Matter: Flows, Cycles and Conservation *Energy can be transferred in various ways and between objects.*

SEP: Developing and Using Models *Use models to describe phenomena.*

MS.LS1.C Organization for Matter and Energy Flow in Organisms

Plants, algae (including phytoplankton), and many microorganisms use the energy from light to make sugars (food) from carbon dioxide from the atmosphere and water through the process of photosynthesis, which also releases oxygen. These sugars can be used immediately or stored for growth or later use. Animals obtain food from eating plants or eating other animals. Within individual organisms, food moves through a series of chemical reactions in which it is broken down and rearranged to form new molecules, to support growth, or to release energy. In most animals and plants, oxygen reacts with carbon-containing molecules (sugars) to provide energy and produce carbon dioxide.

--anaerobic bacteria achieve their energy needs in other chemical processes that do not require oxygen. (*extension: research chemosynthesis)

• How do organisms obtain and use the matter and energy they need to live and grow?

This is the perfect activity to address this standard. Using local plant and animal examples, students can trace the path of energy from the sun to plants, to herbivores and carnivores.

PE: MS-LS1-6 *Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms. [Clarification Statement: Emphasis is on tracing movement of matter and flow of energy.] [Assessment Boundary: Assessment does not include the biochemical mechanisms of photosynthesis.]*

CCC: Energy and Matter: Flows, Cycles and Conservation *Within a natural system, the transfer of energy drives the motion and or cycling of matter.*

SEP: Constructing Explanations and Designing Solutions *Construct a scientific explanation based on valid and reliable evidence obtained from sources and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.*

PE: MS-LS1-7 *Develop a model to describe how food is rearranged through chemical reactions forming new molecules that support growth and/or release energy as this matter moves through an organism. [Clarification Statement: Emphasis is on describing that molecules are broken apart and put back together and that in this process, energy is released.] [Assessment Boundary: Assessment does not include details of the chemical reactions for photosynthesis or respiration.]* (*extension)

CCC: Energy and Matter: Flows, Cycles and Conservation *Matter is conserved because atoms are conserved in physical and chemical processes.*

SEP: Developing and Using Models *Develop a model to describe unobservable mechanisms.*

This activity lays the groundwork for further study to understand how chemical potential energy in the food that any animal eats, becomes the energy needed to live. By following the energy in an ecosystem through these short food chain sets, you can see that energy is moving through the system. But, how that food becomes energy through cellular respiration can be another focus of study for students.

MS.LS2.B Cycles of Matter and Energy Transfer in Ecosystems

Food webs are models that demonstrate how matter and energy are transferred between producers, consumers and decomposers as the three groups interact within an ecosystem. Transfers of matter into and out of the physical environment occur at every level. Decomposers recycle nutrients from dead plant or animal matter back to the soil in terrestrial environments or to the water in aquatic environments. The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem.

- *How do matter and energy move through an ecosystem?*

PE: MS-LS2-3 *Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem. [Emphasis is on describing the conservation of matter and flow of energy into and out of various ecosystems, and on defining the boundaries of the system. Assessment does not include the use of chemical reactions to describe the processes.]*

CCC: Energy and Matter: Flows, Cycles and Conservation *The transfer of energy can be tracked as energy flows through a natural system.*

SEP: Developing and Using Models *Develop a model to describe phenomena.*

MS.PS3.D Energy in Chemical Processes and Everyday Life

The chemical reaction by which plants produce complex food molecules (sugars) requires energy input (i.e. from sunlight) to occur. In this reaction, carbon dioxide and water combine to form carbon-based organic molecules and release oxygen.

Cellular respiration in plants and animals involve chemical reactions with oxygen that release stored energy. In these processes, complex molecules containing carbon react with oxygen to produce carbon dioxide and other materials.

- *How do food and fuel provide energy?*

PE: MS-LS1-6 *Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms. [Clarification Statement: Emphasis is on tracing movement of matter and flow of energy.] [Assessment Boundary: Assessment does not include the biochemical mechanisms of photosynthesis.]*

CCC: Energy and Matter: Flows, Cycles and Conservation *Within a natural system, the transfer of energy drives the motion and or cycling of matter.*

SEP: Constructing Explanations and Designing Solutions *Construct a scientific explanation based on valid and reliable evidence obtained from sources and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.*

PE: MS-LS1-7. *Develop a model to describe how food is rearranged through chemical reactions forming new molecules that support growth and/or release energy as this matter moves through an organism. [Clarification Statement: Emphasis is on describing that molecules are broken apart and put back together and that in this process, energy is released.] [Assessment Boundary: Assessment does not include details of the chemical reactions for photosynthesis or respiration.]*

CCC: Energy and Matter: Flows, Cycles and Conservation *Matter is conserved because atoms are conserved in physical and chemical processes.*

SEP: Developing and Using Models *Develop a model to describe unobservable mechanisms.*

Bird Migration in New Mexico

by Karen Herzenberg

The theme of migration can cover many topics in New Mexico, but the focus of this unit is on the species of migratory birds that make the Middle Rio Grande Valley of New Mexico their home for at least part of the year, and the importance of habitat here in the valley as well as in the places these birds call home during the rest of the year.

Suitable habitat may not be available in one location for all the stages of an animal's life and migration is an adaptation that addresses this issue. **Migration** is the seasonal, cyclic movement of a population of animals, which includes a return to their original location. Food abundance, nest site availability and the ability to tolerate seasonal variations in moisture and temperature are all factors that contribute to whether a particular animal species is migratory. The ability to fly, in some cases long distances, has made this strategy especially useful for birds because they can access a much larger variety of habitats over the course of a year than non-flying animals. The bird species with the longest annual migration is the Arctic tern with an almost pole-to-pole trip twice per year. Most migrations, however, are much shorter. Movements that are daily or a very short distance are not considered to be migration.

The riparian cottonwood forest, or bosque, of New Mexico's Middle Rio Grande Valley is part of a major route of travel for migratory birds. Most avian migration follows natural land forms such as coasts, mountain ranges and rivers. In North America, this occurs primarily in a north-south direction and the various species follow many different routes. Scientists and regulatory agencies in North America have divided up these routes into four flyways through which most migratory birds tend to confine their travels: Pacific, Central, Mississippi and Atlantic. These four flyways converge in Panama and then diverge again in South America.

Most of New Mexico lies in the Central flyway, though the western-most part of the state is considered to be part of the Pacific flyway. In our state, birds tend to travel along the Rio Grande and other rivers and the main mountain chains. Humans, too, have tended to travel along and settle in these locations. If you look at a map of New Mexico's rivers, you can see that many of the original human settlements and current large cities are located in riparian areas.

Avian migrants also converge at other bodies of water and forested areas in flat, open country along the way. These so-called "islands" include Rattlesnake Springs, a spring with riparian vegetation in the middle of the desert near Carlsbad, and the "Melrose Trap," a small patch of trees in the otherwise flat, open plains near Melrose.

Birders (people who observe birds as a recreational activity) travel to these locations during migration and are able to see many species of birds at once in a small area and often have the opportunity to see a rarity or a species that has wandered off its typical migratory route and is not expected in New Mexico. These areas near bodies of water and other habitat corridors or islands tend to have a higher number of avian species, or species richness, because of the habitat resources available. See Activity 22 "Mapping Species Richness" for a Grade 6-12 level classroom activity on this topic.

About 500 of the world's approximately 10,000 bird species have been reported over the last 100 years in New Mexico. About 100 of these are year-round **residents**. These birds have adapted to the climate and geography of New Mexico and are able to find the water, food, shelter and territory (**habitat**) they need to both nest and over-winter. Just because a species is found in New Mexico year-round, does not mean that its range is limited to New Mexico. For example, New Mexico's state bird, the Greater Roadrunner, is a year-round resident but can be found living throughout the Southwestern US.

Most other birds observed in the Middle Rio Grande Valley of New Mexico are migratory: they spend only part of the year here and the rest of the year in other locations. Some are here only in summer, some only in winter and others make a brief stopover on their way between their wintering and nesting grounds. New Mexico's Bosque del Apache National Wildlife Refuge is world-famous for the large numbers of waterfowl and Sandhill Cranes that spend the winter there. The sights and sounds of the Sandhill Cranes' arrival in New Mexico go hand-in-hand with the smell of roasting green chile to announce the beginning of autumn. The following section will highlight several species that follow these migratory patterns.

Hummingbirds

There are more than 300 species of hummingbirds in the world (all in the Americas) and they are adapted to many different habitats including deserts and rainforests and locations at sea-level up to mountain environments above 4,000 meters (13,000 feet). They are primarily nectar-feeders but they eat insects too, and must have insect-protein in order to raise healthy young.

Black-chinned Hummingbird nestlings
photo by Laurel Ladwig

Hummingbirds are astonishing for many reasons. They can fly backwards, upside-down and hover. They are avian record-holders for the most wingbeats per minute and for their extraordinary metabolisms. They are among the smallest birds in the world (adults of most species compare in weight to a penny and the eggs of most species are about the size of a dry pinto bean) and yet some of them migrate huge distances, non-stop, over water.

Four species of hummingbird are typically observed in New Mexico and all are migratory. Broad-tailed and Black-chinned Hummingbirds spend their nesting season here (mid-April through mid-October). Broad-tailed prefer higher elevation habitats and Black-chinned lower, such as the bosque. Black-chinned hummers are the primary patrons of New Mexico's backyard hummingbird feeders. Two other species, Rufous and Calliope Hummingbirds, are observed moving through New Mexico during late summer and early fall. Rufous hummers fight with the Black-chinned over backyard feeders; Calliope are only infrequently observed in urban and rural locations.

North American hummingbirds, along with about 75% of migrants that fly south of the border, go to Mexico and Central America. Only 25% of North America's migratory birds go further into South America.

Human impact on habitat and threats to birds

Humans have had a huge impact on migratory birds. Because of increased human population size and specific human behaviors, migratory birds are facing many threats including decreased habitat, predation by cats, collisions with windows and wind turbines, disorientation due to light pollution and, of course, climate change. Thankfully, humans are now engaged in efforts to decrease these threats around the world and in New Mexico.

The United States is made up of many different biomes and ecosystems which provide suitable habitat for a great diversity of wildlife. There are coastlines, mountains, deserts, prairies, tundra, wetlands and swamps amongst many others. A diversity of birds (and other living things) requires a diversity of habitats. All of these areas include people and have been affected by our activities.

Hairy Woodpecker nestling in cottonwood cavity
photo by Laurel Ladwig

Habitat has been lost at a great rate over the last 150 years due to increases in human population and population density. In urban areas, "empty" lots have been paved, wetlands have been filled in and much of the landscape is "hardscape:" pavement, concrete, stone and metal. Rural areas have seen many thousands of acres of rangeland overgrazed, forest cleared for timber. Various types of habitat have been converted into huge agricultural fields that are chemically treated to prevent other types of plants (or insects) from growing there. Due to habitat loss, birds find fewer stopover points along migration routes. All of these factors have contributed to a decline in bird numbers and diversity in both rural and urban areas. See Activity 23 for a grade 2-6 activity related to avian habitat loss, "Crane Migration."

Climate change only worsens these effects. Some species of birds have begun to migrate or nest earlier, corresponding with earlier warm temperatures. This is problematic because the plants or prey needed to survive migration or to raise young may not yet be available earlier in the year. Conversely, some populations of insects now hatch out or end dormancy earlier, becoming available before birds have begun breeding and effectively making them unusable as a food source for nesting birds. Birds' ranges are changing as well. For example, some birds that formerly were only seen in the southern part of New Mexico have begun to appear with some regularity in the Albuquerque area. Increases in severe weather events due to climate change such as drought and heavy rainstorms have an impact on avian life as well. Growing numbers of wildfires and escalating fire severity are destroying vast swaths of forest habitat with effects made worse by years of fire suppression. Coastal wetlands and deltas have been altered by tropical storms and by rising sea levels. All of these shifts affect not only birds, but humans as well.

Research and monitoring of birds

People are beginning to make the changes necessary to address threats to birds, including climate change. Many projects are underway to increase, improve and restore bird habitat in urban and rural areas. Long-term monitoring by professional researchers and citizen scientists has paved the way for us to address the effects of climate change (including loss of habitat). Bird banding is one of many such efforts. Research collected by banders can contribute to habitat conservation efforts, to education about threats to birds and to advances in the science of climate change.

Bird banding is a method of monitoring in which birds are captured, tiny metal or plastic bands engraved with unique identification numbers are placed on one or both of their legs, data about the birds are collected and, finally, the birds are released. All of this occurs over a span of minutes. If and when the birds are recaptured by other scientists or rescuers of injured birds, or found dead, the person encountering that bird can report the band number to the U.S. Geological Survey at the web site https://www.pwrc.usgs.gov/bbl/bblretrv/index.cfm. If nothing else, the original banding data together with recapture data can give insights as to the bird's age and the distance it traveled. Most birds are not recaptured repeatedly but for those that have been, information about a particular bird's life can contribute to the big picture of the natural history of that species. All of the data together from banders throughout the world and over the course of scores of years begins to show patterns in timing and movement, and this information, when compared with other knowledge and data about natural history and climate, can help us to understand and inform our past, present and future actions.

Rio Grande Bird Research (RGBR) is a team of biologists and volunteers who have been monitoring songbirds at the Rio Grande Nature Center State Park since 1979. Like similar data collected around the world, their work shows some dramatic changes in bird populations and habits over this period in time. The lessons in this section are based on data collected by RGBR.

The Rio Grande Bird Research banders conduct monitoring either once or twice a week for ten week periods in fall and winter. They do not band birds at the Park during breeding season. The duration of each daily monitoring session is six hours.

Twenty 2 x 6 meter (6 x 20 foot) mist nets are set up between poles at different locations around the premises of the Park just before dawn. Mist nets are lightweight mesh with holes for the capture of songbirds (see photo at right). Occasionally an insect or hummingbird is caught or, at the other end of the spectrum, a raptor or a roadrunner. The banders go on a round checking for captured birds every 25 minutes. Any birds that are caught are gently removed from the net, placed in a small cloth bag for their protection and brought to the banding station.

Photographs by Laurel Ladwig

Each bird's species and its time & place of capture are logged in and the following data are collected for each bird: band number (new or recapture), wing and tail length; weight; condition of wing, tail and body feathers; and amount of muscle and fat present. Using these data and other observations of plumage, the species (and sometimes subspecies) is identified and the age and sex of some birds can be determined. Information about weather conditions and other birds and animals observed during the course of the monitoring session is also recorded. All of these data are then logged into the bird banding database where they become accessible to scientists all over the world.

> "But to the old timer the banding of new birds becomes merely pleasantly routine; the real thrill lies in the recapture of some bird banded long ago, some bird whose age, adventures, and previous condition of appetite are perhaps better known to you than to the bird himself."
>
> - *Aldo Leopold, A Sand County Almanac*

A note about names

Birds and other animals and plants have many common names (see the box belowabout Greater Roadrunners) and because of this, there can sometimes be confusion about which thing is being discussed. Sometimes it doesn't matter (you say toe-may-toe, I say toe-mah-toe) but in other contexts it can be important: it can mean life or death if we're discussing which mushrooms are or are not edible! For more information about scientific names, see the background section of Activity 10, "A Rose by Any Other Name."

In addition to names, scientists use four-letter "alpha codes" to save time when collecting data or writing notes. If the name is one word, the code will be that word's first four letters (MALL for Mallard). If the name is two words, the code will usually be the first two letters of each name (COHA for Cooper's Hawk). If the name includes a hyphenated first name, the code uses the first letter of the first hyphenated word, the first letter of the second hyphenated word and the first two letters of the second word (WCSP for White-crowned Sparrow). There are a few exceptions like LAZB for Lazuli Bunting which differentiates it from LARB for Lark Bunting...otherwise they'd both be LABU. There are also six-letter codes in use, but, for the purpose of this curriculum we will stick with the four-letter codes.

The Migratory Bird Treaty Act

The Migratory Bird Treaty Act regulates the acquisition, possession and disposal of migratory birds in the U.S. and is administered and enforced by the U.S. Fish and Wildlife Service. Living or dead birds, and their feathers, bones, nests and eggs may only be handled according to special regulations — and law-breakers may face time in prison and up to $10,000 in fines. Scientists, bird rehabbers, bird banders and other professionals receive special training so that they may work with these protected species, and are then issued a permit which must be renewed annually. For more information on the act, contact the U.S. Fish and Wildlife Service's Migratory Bird Program or visit https://www.fws.gov/birds/policies-and-regulations/laws-legislations/migratory-bird-treaty-act.php.

Interesting Facts About Bird Migration

1) About 40% of the world's 10,000 birds migrate regularly. Even birds that don't fly may migrate, including some species of penguins (they swim) and Australia's emus (they walk).

2) The Bar-headed Goose is the highest-flying migrant. It reaches altitudes of up to 8.8 kilometers (5.5 miles) above sea level - more than twice as far above sea level as the highest mountains in New Mexico!

3) The Great Snipe maintains speeds of up to 96 kph (60 mph) over the course of its 6,800 kilometer (4,200 mile) migratory path. No other bird (or other animal of any kind) travels at such high speeds for such long distances.

4) The Arctic Tern, is the world's leader in miles logged per year. These birds fly twice annually between the Arctic and Antarctica!

5) The Swainson's Hawk has the one of the longest migrations of any raptor found in North America. It spends the breeding season in open lands from Alaska to northern Mexico and winters in Argentina. Swainson's Hawks can be found nesting in grasslands and agricultural lands throughout New Mexico.

6) Some Lesser Sandhill Cranes (a subspecies of the Sandhill crane) breed in Siberia but winter in New Mexico!

7) The Bar-tailed Godwit flies the longest distance non-stop of any bird: 11,000 kilometers (7,000 miles) from Alaska to New Zealand in just 8 days!

8) **Hyperphagia** is a state in which birds bulk up on food prior to migration in order to store fat that they'll use during long and often non-stop journeys. Some birds almost double their body weight during hyperphagia! For example, a Prothonotary Warbler was captured during migration by Rio Grande Bird Research at the Rio Grande Nature Center State Park. This is an Eastern species and so it was way off course, maybe blown in by a storm system. It was captured twice. When first measured it scored a low number for the amount of fat present on its body. It was recaptured a week later and scored the highest number possible.

Adapted from National Audubon's *Nine Awesome Facts about Bird Migration* (https://www.audubon.org/news/9-awesome-facts-about-bird-migration)

MIGRATION - by Linda Rockwell

While you were sleeping last night
I flew 300 miles without stopping or eating.
An ounce of bright feathers, heart, muscle,
And bones as light as air.
Danger everywhere:
Predators, exhaustion, windows that look like sky.
Today I eat seeds in your garden.
You do not notice a miracle.

Selected Bosque Bird Information Cards

Some bird species can be found all year at one location and are considered "year-round residents" of that location. Other species are present at a location only during certain times of year and are considered "migrants." They may be present during breeding season, wintering season or during spring or fall (or both) migrations.

Each of the following cards represents one of these categories of migratory status and presents photos and information about a New Mexico bird that fits the category. Teachers could use the cards as background reading for themselves or students or as part of an activity of some kind with students. For example, individual students or groups could be in charge of presenting information from the cards to the rest of the class; the cards could be used as a springboard for further research on birds of New Mexico or students could prepare some kind of graphic comparing the migratory status of the different birds in order to teach others in the school community.

In addition to the seven cards below, use the list "Migratory Birds Frequently Found in New Mexico" in this chapter for extension activities in conjunction with these cards or independently.

Newly banded Lazuli Bunting

Photograph by Laurel Ladwig

Year-round Resident

Greater Roadrunner ***(Geococcyx californianus)***

The Greater Roadrunner is a member of the family of birds called Cuckoos. Birds in the cuckoo family can be found throughout the world and are adapted to many different environments. The Greater Roadrunner favors arid lands like New Mexico and is year-round resident here. Not surprisingly, roadrunners are often found on or along roadways and edges of agricultural fields in rural as well as more urban areas like Albuquerque. They are adapted to living around humans and consequently are known by many different regional names (roadrunner, paisano, chaparral and correcaminos are just a few used in New Mexico).

Photograph by Laurel Ladwig

Summer Resident

Black-chinned Hummingbirds ***(Archilochus alexanderi)***

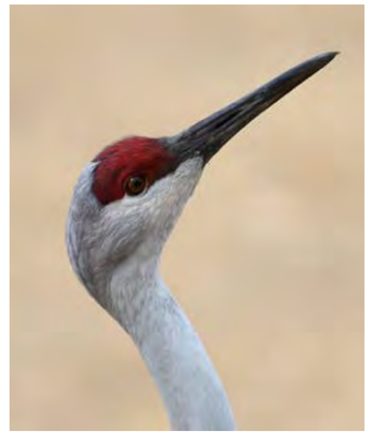
Black-chinned Hummingbirds are among the most adaptable of all hummingbirds and are found in urban areas and recently disturbed natural areas as well as pristine natural areas. They winter along the Pacific coast of Mexico and Central America and migrate north to breeding grounds that extend from northern Mexico up into southern Canada. In the southwestern US, they are most common in canyons and along rivers. They are in New Mexico from about mid-April through mid-October and are the most common nesting bird in the bosque.

Photograph by Laurel Ladwig

Winter Resident

Sandhill Crane ***(Antigone canadensis)***

Sandhill Cranes nest in wetlands near the Rocky Mountains in Colorado and north into Canada. Some individuals of a subspecies called the Lesser Sandhill Crane actually travel all the way to Siberia to nest. These birds begin to arrive in New Mexico in September in pairs, trios and fours: family units with young of the year. Later in September and on into October, huge, high-flying flocks arrive or stop-in on their way to parts further south. Over the winter, thousands of Sandhill Cranes reside throughout New Mexico. They migrate back to northern nesting grounds in February and March.



Photograph by Laurel Ladwig

Spring and Fall Migration

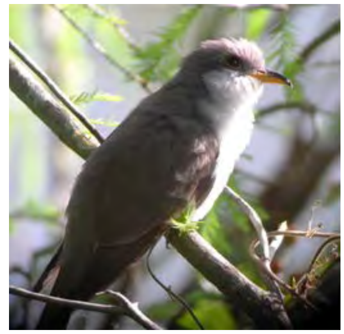
Wilson's Warbler ***(Cardellina pusilla)***

Wilson's Warblers pass through our area during migration. They can be found in Albuquerque in April through June when traveling north to their breeding grounds and August through October when heading back south for the winter. They migrate at night either singly or in small groups of other Wilson's Warblers or other warbler species. Wilson's Warblers eat mostly insects and occasionally berries and look for suitable habitat during migration. They are most often found near the bosque but can be see throughout the city, gleaning trees for insects. They breed throughout Alaska and Canada and there are small pockets of birds that breed more southerly in the American west. They build a cup-shaped nest on the ground under bunches of grass or at the base of shrubs.

Photograph by Laurel Ladwig

Summer Resident

Yellow-billed Cuckoo (*Coccyzes americanus*)



Photograph by Laurel Ladwig

Yellow-billed Cuckoos nest in the Rio Grande bosque. The timing of their breeding is tied to the local food supply. They begin breeding when food is abundant and their entire breeding cycle takes only 17 days, from egg-laying to fledging. Within minutes after they are born, baby cuckoos can climb and perch using their feet and bills. The nestlings have bursting feather sheaths which allow them to transform into fully feathered young cuckoos in only two hours. The western sub-species was classified as threatened in October 2014 and much of the Middle Rio Grande bosque is designated as critical habitat for the species. It is usually heard rather than seen.

Listen to the sounds made by Yellow-billed Cuckoos:
https://www.allaboutbirds.org/guide/Yellow-billed_Cuckoo/sounds

Winter Resident

White-crowned Sparrow *(Zonotrichia leucophrys)*

White-crowned Sparrows winter here and can be found in flocks along roadsides and in grain fields, and close to thickets and shrubs. White-crowned Sparrows have magnetite in the fascia of their heads and necks that may make them capable of magnetic navigation. Because male White-crowned Sparrows learn the songs they grow up with and typically breed close to where they were raised, song dialects frequently form. Males on the edge of two dialects may be bilingual and able to sing both dialects. A migrating White-crowned Sparrow was once tracked moving 480 kilometers (300 miles) in a single night. Alaskan White-crowned Sparrows migrate about 4000 kilometers (2,600 miles) to winter in Southern California. The oldest recorded White-crowned Sparrow was 13 years 4 months old.

Photograph by Laurel Ladwig

Variable. Present year-round.

Chipping Sparrow ***(Spizella passerina)***

Chipping Sparrows are present in the Albuquerque area throughout the year. They are most often observed in town during migration and are also found in low numbers in the winter. During breeding season they are most easily observed in the mountains and foothills. Chipping Sparrows can be seen in trees, but also forage on the ground. They eat seeds from a variety of grasses and add extra protein to their diet during breeding season by eating insects.

Photograph by Ashli Maruster Gorbet

Written and edited by Letitia Morris, Karen Herzenberg and Laurel Ladwig.

More information:

Bosque Education Guide
http://www.nmnaturalhistory.org/bosque-education-guide.html
Some curriculum materials and activities are available in Spanish.

Rio Grande Bird Research
http://www.rgbr.org/RGBR_site/Rio_Grande_Bird_Research.html

About bird banding
https://www.pwrc.usgs.gov/BBL/homepage/aboutbanding.cfm

Reporting banded birds
http://www.fws.gov/birds/surveys-and-data/bird-banding/reporting-banded-birds.php

Bird threats
http://abcbirds.org/threats/

US Fish and Wildlife Service Migratory Bird Division
http://www.fws.gov/birds/about-us.php
Spanish version available: https://www.fws.gov/birds/grants/neotropical-migratory-bird-conservation-act/nmbca-espanol.php

Audubon article on the Migratory Bird Treaty Act
https://www.audubon.org/news/the-migratory-bird-treaty-act-explained

Bird banding codes chart
https://www.pwrc.usgs.gov/BBl/manual/speclist.cfm

All About Birds is an online guide to birds of North America which includes images, sounds, identifying features, range maps and life history of hundreds of birds.
https://www.allaboutbirds.org

Audubon's guide to birds of North America is available in Spanish here: http://www.audubon.org/es/guia-de-aves

Migratory Birds Frequently Found in New Mexico

Migratory species mentioned / described within this introduction and associated lessons are marked with an asterisk(*).

Students could research any of these species to expand their knowledge of New Mexico migrants.

Snowy Egret (*Egretta thula*)

Green Heron (*Butorides virescens*)

Snow (*Anser caerulescens*) and/or Ross' Goose (*Anser rossii*)

American Wigeon (*Mareca americana*)

Northern Shoveler (*Spatula clypeata*)

Green-winged Teal (*Anas crecca*)

Canvasback (*Aythya valisineria*)

Ring-necked Duck (*Aythya collaris*)

Hooded Merganser (*Lophodytes cucullatus*)

Turkey Vulture (*Cathartes aura*)

Swainson's Hawk*(*Buteo swainsoni*)

Ferruginous Hawk*(*Buteo regalis*)

Bald Eagle (*Haliaeetus leucocephalus*)

Osprey (*Pandion haliaetus*)

Sandhill Crane* (*Antigone canadensis*)

Ring-billed Gull (*Larus delawarensis*)

Yellow-billed Cuckoo* (*Coccyzus americanus*)

Spotted Sandpiper (*Actitis macularius*)

Common Nighthawk (*Chordeiles minor*)

Black-chinned Hummingbird* (*Archilochus alexandri*)

Calliope Hummingbird* (*Selasphorus calliope*)

Broad-tailed Hummingbird* (*Selasphorus platycercus*)

Rufous Hummingbird* (*Selasphorus rufus*)

Western Kingbird (*Tyrannus verticalis*)

Barn Swallow (*Hirundo rustica*)

Yellow Warbler (*Setophaga petechia*)

Wilson's Warbler* (*Cardellina pusilla*)

Common Yellowthroat (*Geothlypis trichas*)

Yellow-breasted Chat (*Icteria virens*)

Summer Tanager (*Piranga rubra*)

Western Tanager (*Piranga ludoviciana*)

Black-headed Grosbeak (*Pheucticus melanocephalus*)

Blue Grosbeak (*Passerina caerulea*)

Lazuli Bunting* (*Passerina amoena*)

Chipping Sparrow* (*Spizella passerina*)

White-crowned Sparrow* (*Zonotrichia leucophrys*)

Dark-eyed Junco (*Junco hyemalis*)

Bullock's Oriole (*Icterus bullockii*)

Pine Siskin* (*Spinus pinus*)

American Goldfinch* (*Spinus tristis*)

47. Who Flew Where?

Description: Students explore bird migration using actual banded bird recovery data; students measure a scaled distance of where 20 different birds were found from where they were originally banded. A second part has students locating those places on a map of western North America.

Objective: Students will see and understand the distances some birds fly in their migration. Students will be able to identify that appropriate habitat is critical to birds' survival in breeding, migrating and wintering locations.

Materials:

Part A

- Bird Recapture Data cards showing 20 different individual birds on the Rio Grande Bird Research recapture list (there are 11 species included)
- Measuring tape (25 - 50 meter is best)
- Master copy of data page for teacher
- Space that is at least 43 meters/130 feet long; could be hallway, gym, school yard.

Part B

- Copies of map for each student or small group
- Copies of "Who Flew Where" Banded Bird Recaptures data sheets for each student or group
- Maps, atlases, computer for map search-- for student use
- Bird Recapture Data cards used in Part A
- Scissors
- Tape and/or glue

47. Who Flew Where?

Grades: 4-8
Time: at least 2 class periods
Subjects: science, social studies/geography, math
Standards: see end of migration activities

Terms: *migration, bird banding, habitat, ornithologist, range*

Background: Through bird banding, biologists are documenting the health, size, age, and travels of birds. The Bird Banding Laboratory makes this statement about what has been learned through banding birds:

> "In this way we have learned that some species go south in one pathway and return north by another pathway. Nesting and wintering grounds have been located for some species, and specific nesting grounds have been connected to specific wintering areas. The Arctic Tern makes the longest migration flight of any living species, making an annual round trip flight of 40,234 km (25,000 miles). The migration routes used by this species have been determined by band recoveries in part."

This activity uses data from Rio Grande Bird Research and their long-term banding project at the Rio Grande Nature Center State Park, in Albuquerque's bosque. They do band a few other places such as Bosque del Apache National Wildlife Refuge, Capilla Peak in the Manzano Mountains, and beginning in 2014, Valle de Oro National Wildlife Refuge.

NOTE: Rio Grande Bird Research primarily bands birds during the fall and early spring. The majority of birds they band are migrating or wintering and that is shown in the map the students create. *Birds that breed in the Albuquerque area and fly south for the winter are typically not banded*, because the group does not band during the nesting season and they are already headed south when banding starts in the fall.

Procedure:

- Class discussion about migration and bird banding:

  What is the connection between people and birds? What is important about birds?

  Think, pair share: Give a few minutes for students to individually think about this. Then have them discuss in small groups, finally ask the whole class to share their ideas.

  Why do scientists study birds? What can we learn by studying birds?

  Bird scientists or **ornithologists** use different techniques to study birds. Field ornithologists may observe birds in the wild using binoculars. **Bird banding** is one way field ornithologists monitor wild birds. We can determine the **range** of that species, where that type of bird can be found through its lifetime.

How can we define migration?

Warm-up activity.

Some of the birds are wintering in this area, some are nesting, some are migrating through, and some are here year-round.

Can you think of birds you have seen only in the summer here?

Can you think of birds you have seen only in the winter in New Mexico?

Can you think of birds that you can see all year round in your neighborhood?

Put the following bird names on the board, ask the students to match the bird with its migratory status.

Greater Roadrunner -- (year-round resident in New Mexico)

Black-chinned Hummingbirds -- (nest in New Mexico, migrates south for the winter)

Sandhill Crane -- (nests far to the north, migrates to New Mexico and stays the winter)

You can share information from the Introduction section about each of these three species and additional species from the selected bosque bird information cards.

What is bird banding?

Bird banders catch birds in large nets called mist nets. They then observe the birds closely and record data about them. Banders put a ring around the bird's leg that is imprinted with a unique number. If someone finds a banded bird they should report it to the US Fish and Wildlife Service; the information is then relayed back to the original banders.

What are scientists learning by catching the birds and banding them that they wouldn't know just by looking at them? (Also, see Introduction).

Bird Banders find out the age, sex of the bird, measure their wing & tail length, weight, amount of fat & muscle, and the amount of feather wear. This provides information about the health of each bird.

If a banded bird is recaptured, what can we find out from that?

This is the activity we will be doing now--focusing on bird banding recapture data from the Rio Grande Bird Research team.

This activity focuses on the scaled distances between where birds were banded and later recaptured. The second section has students locate those places on a map. Students can see that birds do not stay in a narrow corridor--they have wings and can fly in many directions.

Part A

- Hand each student a Bird Recapture Data card. There are 20 different cards, make additional copies to duplicate a few species, if needed for your class size.

  Have the students look at the distance between the location banded and location recaptured.

- Have everyone line up by distance.

  Spread out according to the scaled distance for the activity.

  Determine a starting point at one end of your large space--that will be Albuquerque.

  Tip: if the area has standard floor tiles that are one-foot square, use the "feet" measurement for this activity--with students counting the tiles for the distance. Otherwise, students will need to use meter sticks or measuring tape; the longest/farthest is 43 meters/130 feet.

- Pull the group back and have each student tell:

  Kind of bird?

  Where banded?

  Where recaptured?

  How many kilometers between location banded and location recaptured?

  There are several birds of the same species that have been recaptured. Have students with the same species gather together and compare similarities and differences of each one--Where were they banded and recaptured? It lived at least how long, etc?

  What do birds need to survive?

- All animals need appropriate **habitat**. Review what habitat is:

  Food, water, shelter, space in the appropriate arrangement

  Finding these birds where they were first banded shows that there was appropriate habitat for them at that time.

  Identify elements of appropriate habitat for some of the species of banded birds.

  How can we as citizens and land managers ensure that appropriate habitat is here when birds migrate through? Answers will vary.

  What is the furthest distance for any band recovery related to Rio Grande Bird Research? Note: it was banded elsewhere and recovered in Albuquerque.

  Originally banded in Fairbanks, Alaska, recaptured by RGBR in Albuquerque: 4319 kilometers, 2684 miles away.

Which bird banded by Rio Grande Bird Research in Albuquerque was recovered the greatest distance away? How far was this? Where was it recovered?

Leduc, Alberta, Canada: 2110 kilometers, 1311 miles

Two birds were banded elsewhere in New Mexico—Where? Where were they later found?

White-crowned Sparrow: Banded at Bosque del Apache, New Mexico on 11-21-1999, found in Quincy, California on 11-6-2002

Ferruginous Hawk: Banded in Catron County, New Mexico on June 18, 1997, found in San Carlos, Arizona on August 8, 1997

Part B

- Hand out the map page to each student or small group. Printing the map on 11 x 17 paper makes it large enough for the activity.
- Hand out the one page "Who Flew Where" Banded Bird Recaptures data sheet.

There are circles with bird silhouettes and a four-letter name on each circle along the right and left margins of the paper. Students will be cutting out those circles and placing them on the map in the proper location where they were found.

The locations are noted with the name of the nearest town, as well as longitude and latitude. There are two versions of the map of Western North America: one with stars showing the locations where birds were found, and one without the stars--students will need to use the latitude/longitude lines to correctly place them.

- Students should glue or tape the icon of the bird to the location where they were found on the map. Draw arrows from the banding location to the recapture location.

You may want students to use maps, atlases or the internet to find the communities where some of the birds were found.

Have students add the names of the states (and Canadian Provinces) to their map.

Have students color-code the bird species icon and the appropriate star, and place the icon near the star. There are 11 species, pick colors for each.

Is this a map of birds that typically nest in Albuquerque? Reside year-round in Albuquerque? Winter in Albuquerque?

- Using the Bird Recapture Data cards from Part A section above, look at the dates when the birds were banded and the dates when recaptured.

Rio Grande Bird Research primarily bands birds during the fall and early spring. The majority of birds they band are migrating or wintering and that is shown in the map. Birds that breed in the Albuquerque area and fly south for the winter are typically not banded because they are not present at this time of the year.

What patterns can you see by looking at your finished map?

Answers will vary, but most go north to south. Most birds nest in the north and fly south for the winter.

What areas need appropriate habitat for birds that are residents or migrants?

Answers will vary--but good habitat at stopover spots during migration are extremely important. They must be able to feed and build up their fat stores for continued flight. So there must be proper habitat throughout their migration path.

Assessment:

- Have students describe the seasonal pattern of bird migration.
- Have students draw their own bird migration map.
- Are students able to find locations by longitude and latitude?
- Have students write an argument about the human impacts on migrating birds. [Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.]
- Have students write an argument about the behaviors of birds to allow them to survive different seasons. [Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors affect the probability of successful reproduction.]

Extensions:

- Phenology Challenge:

  Have students record when they see the first migrating Sandhill Cranes arriving in the fall, and heading north in the spring.

  When do the first hummingbirds arrive in the spring?
- Students can research a variety of New Mexico migrants using the list in the Introduction.
- Visit the eBird website. Students can click on "Explore Data" and there are options to look for information in various ways. Probably the most "student-friendly" would be "Species Maps" and "Bar Charts." By clicking on "Species Maps" students can explore where in the world a particular species of bird is found and then can narrow the search to certain times of the year or certain locations in the world. By clicking on "Bar Charts," students can explore shifts in numbers of birds seen at a particular location throughout the year.
- Compare the map the students made with maps of other bird migration flyway maps. How does theirs compare? There are 20 data points on the map they made, many, many more records are assembled to make the national maps. But it takes years of research to be able to make such a map.
- Compare the age of the birds--find the longest to shortest time between banding and recapture. Recapture does not necessarily indicate death, but does give a hard number to researchers to know that an individual bird lived at least that long.

- Calculate the number of months between banding and recapture, and list the birds in the order of how long we know they lived. Here are some of the answers:

  What is the longest time between banding and recapture?
  American Kestrel: 57 months, May 29, 1996 to March 21, 2001
  White-crowned Sparrow: 35 months, November 21, 1999 to November 6, 2002
  Song Sparrow: 29 months, October 1, 1996 to March 10, 1999
  White-crowned Sparrow: 27 months, October 7, 1996 to January 28, 1999
  House Finch: 26 months November 6, 1988 to January 21, 1991
- Students can research each species to identify where each one breeds--which were banded on likely breeding locations?
- Students can research bird migration records--some birds fly from the far north to the far south two times a year--an astounding feat for a small animal.
- Research bird banding--look for images of the nets, pliers, bands etc., used to band birds. Who bands birds?
- Research the type of habitat the birds needed where they travelled to or from--for example, an AMGO (American Goldfinch) was banded in Albuquerque in the bosque, but found in Heber, Utah. What habitat is in the area of Heber, Utah?
- Students can research threats to birds: habitat reduction, predation by pets, collisions with windows and wind turbines, disorientation due to light pollution and climate change.

Resources/References:

eBird is a searchable online database of bird sightings throughout the world. Many of the sightings were entered by citizen scientists. Teachers and students may be familiar with eBird because of the annual Great Backyard Bird Count. http://ebird.org/content/ebird/

National Geographic publishes a map, Migration Flyways of North America, that can be purchased here (in the past it was a supplement to the magazine)

http://shop.nationalgeographic.com/ngs/product/maps/wall-maps/specialty-maps/bird-migration-in-the-americas-thematic-map?npd&npd&code=SR50002&code=

Interactive map documenting migratory movements of bird populations spanning the entire year for 118 species throughout the Western Hemisphere prepared by **Cornell Lab of Ornithology**

https://www.allaboutbirds.org/mesmerizing-migration-watch-118-bird-species-migrate-across-a-map-of-the-western-hemisphere/

Partners in Flight / Compañeros en Vuelo / Partenaires d'Envol was launched in 1990 in response to growing concerns about declines in the populations of many land bird species at their wintering grounds. http://www.partnersinflight.org

Who Flew Where?

Banded Bird Recaptures, Rio Grande Bird Research, Inc.

(1) Sharp-shinned Hawk Williamsburg, NM (33ºN 107ºW)
Banded: October 12 1995 · Recaptured: October 27, 1997

(2) Cooper's Hawk Salt Lake City, UT (40ºN 111ºW)
Banded: August, 28, 1995 · Recaptured: April 12, 1996

(3) Ferruginous Hawk San Carlos, Arizona (33ºN 110ºW)
Banded: June 18, 1997 · Recaptured: August 8, 1997

(4) American Kestrel Albuquerque, NM (35ºN 106ºW)
Banded: May 29, 1996 · Recaptured: March 21, 2001

(5) Song Sparrow Lander, WY (42ºN 108ºW)
Banded: October 26, 1997 · Recaptured: April 8, 1998

(6) Song Sparrow Durango, CO (37ºN 107ºW)
Banded: October 1, 1996 · Recaptured: March 10, 1999

(7) White-crowned Sparrow Bosque del Apache, NM (33ºN 106ºW)
Banded: November 17, 1990 · Recaptured: April 7, 1991

(8) White-crowned Sparrow Leduc, Alberta, Canada (53ºN 113ºW)
Banded: January 10, 1978 · Recaptured: May 12, 1978

(9) White-crowned Sparrow Prescott, AZ (34ºN 112ºW)
Banded: October 7, 1996 · Recaptured: January 28, 1999

(10)White-crowned Sparrow Evans, CO (40ºN 104ºW)
Banded: April 15, 1994 · Recaptured: later in1994

Fairbanks, Alaska (64ºN 147ºW) **White-crowned Sparrow (11)**
Banded: August 26, 1991 · Recaptured: October 30, 1993

Quincy, California (40ºN 121ºW) **White-crowned Sparrow (12)**
Banded November 21, 1999 · Recaptured November 6, 2002

Ogden, UT (41ºN 111ºW) **Lazuli Bunting (13)**
Banded: August 20, 1989 · Recaptured: May 4, 1991

Albuquerque, NM (35ºN 106ºW) **House Finch (14)**
Banded: November 6, 1988 · Recaptured: January 21, 1991

Tijeras, NM (35.08ºN 106.37ºW) **Pine Siskin (15)**
Banded: November 6, 1996 · Recaptured: December 30, 1996

Tijeras, NM (35ºN 106ºW) **Pine Siskin (16)**
Banded: October 13, 1995 · Recaptured: February 1, 1996

Pojoaque, NM (35.89ºN 106.00ºW) **Lesser Goldfinch (17)**
Banded: September 30, 1996 · Recaptured: August 19, 1998

Raton, NM (36.89ºN 104.44ºW) **Lesser Goldfinch (18)**
Banded: September 6, 1996 · Recaptured: August 9, 1998

West Jordan, UT (40ºN 111ºW) **American Goldfinch (19)**
Banded: January 25, 2003 · Recaptured: August 16, 2004

Heber, UT (40ºN 111ºW) **American Goldfinch (20)**
Banded: October 12, 1996 · Recaptured: June 15, 1997

Bird Banding Codes Demystified:
One word names: first four letters (MALL for Mallard).
Two word names: usually the first two letters of each name (COHA for Cooper's Hawk).
Hyphenated first name: the first letter of the first hyphenated word, the first letter of the second hyphenated word and the first two letters of the second word (WCSP for White-crowned Sparrow).
[Exceptions are: LAZB for Lazuli Bunting which differentiates it from LARB for Lark Bunting...otherwise they'd both be LABU.]

1

Bird Species: Sharp-shinned Hawk

Bird banded at this location:
Albuquerque, New Mexico (35.13ºN 110.67ºW)
Bird banded on this date: **October 12 1995**
Bird recaptured at this location:
Williamsburg, New Mexico (33ºN 107ºW)
Bird recaptured on this date: **October 27, 1997**
Distance between banding & recapture locations:
~225 km (140 miles)
Scaled distance for activity: **~2.25 meters (8 feet)**

2

Bird Species: Cooper's Hawk

Bird banded at this location:
Albuquerque, New Mexico (35.13ºN 110.67ºW)
Bird banded on this date: **August, 28, 1995**
Bird recaptured at this location:
Salt Lake City, Utah (40ºN 111ºW)
Bird recaptured on this date: **April 12, 1996**
Distance between banding & recapture locations:
~800 km (500 miles)
Scaled distance for activity: **~8 meters (26 feet)**

3

Bird Species: Ferruginous Hawk

Bird banded at this location:
Catron County, New Mexico (33ºN 108ºW)
Bird banded on this date: **June 18, 1997**
Bird recaptured at this location:
San Carlos, Arizona (33ºN 110ºW)
Bird recaptured on this date: **August 8, 1997**
Distance between banding & recapture locations:
~200 km (125 miles)
Scaled distance for activity: **~2 meters (7 feet)**

4

Bird Species: American Kestrel

Bird banded at this location:
Albuquerque, New Mexico (35.13ºN 110.67ºW)
Bird banded on this date: **May 29, 1996**
Bird recaptured at this location:
Albuquerque, New Mexico (35ºN 106ºW)
Bird recaptured on this date: **March 21, 2001**
Distance between banding & recapture locations:
~0 km (0 miles)
Scaled distance for activity: **~0 meters (0 feet)**

5

Bird Species:
Song Sparrow

Bird banded at this location:
Albuquerque, New Mexico (35.13°N 110.67°W)
Bird banded on this date: **October 26, 1997**
Bird recaptured at this location:
Lander, Wyoming (42°N 108°W)
Bird recaptured: **April 8, 1998**
Distance between banding & recapture locations:
~925 km (575 miles)
Scaled distance for activity: **~9.25 meters (30 feet)**

6

Bird Species:
Song Sparrow

Bird banded at this location:
Albuquerque, New Mexico (35.13°N 110.67°W)
Bird banded on this date: **October 1, 1996**
Bird recaptured at this location:
Durango, Colorado (37°N 107°W)
Bird recaptured on this date: **March 10, 1999**
Distance between banding & recapture locations:
~300 km (190 miles)
Scaled distance for activity: **~3 meters (9 feet)**

7

Bird Species:
White-crowned Sparrow

Bird banded at this location:
Albuquerque, New Mexico (35.13°N 110.67°W)
Bird banded on this date: **November 17, 1990**
Bird recaptured at this location:
Bosque del Apache, New Mexico (33°N 106°W)
Bird recaptured on this date: **April 7, 1991**
Distance between banding & recapture locations:
~144 km (90 miles)
Scaled distance for activity: **~1.44 meters (5 feet)**

8

Bird Species:
White-crowned Sparrow

Bird banded at this location:
Albuquerque, New Mexico (35.13°N 110.67°W)
Bird banded on this date: **January 10, 1978**
Bird recaptured at this location:
Leduc, Alberta, Canada (53°N 113°W)
Bird recaptured on this date: **May 12, 1978**
Distance between banding & recapture locations:
~2100 km (1300 miles)
Scaled distance for activity: **~21 meters (69 feet)**

9

Bird Species:
White-crowned Sparrow

Bird banded at this location:
Albuquerque, New Mexico (35.13°N 110.67°W)
Bird banded on this date: **October 7, 1996**
Bird recaptured at this location:
Prescott, Arizona (34°N 112°W)
Bird recaptured on this date: **January 28, 1999**
Distance between banding & recapture locations:
~540 km (335 miles)
Scaled distance for activity: **~5.4 meters (18 feet)**

10

Bird Species:
White-crowned Sparrow

Bird banded at this location:
Albuquerque, New Mexico (35.13°N 110.67°W)
Bird banded on this date: **April 15, 1994**
Bird recaptured at this location:
Evans, Colorado (40°N 104°W)
Bird recaptured: **1994**
Distance between banding & recapture locations:
~650 km (400 miles)
Scaled distance for activity: **~6.5 meters (21 feet)**

11

Bird Species:
White-crowned Sparrow

Bird banded at this location:
Fairbanks, Alaska (64°N 147°W)
Bird banded on this date: **August 26, 1991**
Bird recaptured at this location:
Albuquerque, New Mexico (35.13°N 110.67°W)
Bird recaptured on this date: **October 30, 1993**
Distance between banding & recapture locations:
~4300 km (2677 miles)
Scaled distance for activity: **~43 meters (130 feet)**

12

Bird Species:
White-crowned Sparrow

Bird banded at this location:
Bosque del Apache, New Mexico (33°N 106°W)
Bird banded on this date: **November 21, 1999**
Bird recaptured at this location:
Quincy, California (40°N 121°W)
Bird recaptured on this date: **November 6, 2002**
Distance between banding & recapture locations:
~1425 km (885 miles)
Scaled distance for activity: **~14.25 meters (47 feet)**

13

Bird Species:
Lazuli Bunting

Bird banded at this location:
Albuquerque, New Mexico (35.13ºN 110.67ºW)
Bird banded on this date: **August 20, 1989**
Bird recaptured at this location:
Ogden, Utah (41ºN 111ºW)
Bird recaptured: **May 4, 1991**
Distance between banding & recapture locations: ~
~825 km (512 miles)
Scaled distance for activity: **~8.25 meters (27 feet)**

14

Bird Species:
House Finch

Bird banded at this location:
Albuquerque, New Mexico (35.13ºN 110.67ºW)
Bird banded on this date: **November 6, 1988**
Bird recaptured at this location:
Albuquerque, New Mexico (35ºN 106ºW)
Bird recaptured: **January 21, 1991**
Distance between banding & recapture locations:
~0 km (0 miles)
Scaled distance for activity: **~0 meters (0 feet)**

15

Bird Species:
Pine Siskin

Bird banded at this location:
Albuquerque, New Mexico (35.13ºN 110.67ºW)
Bird banded on this date: **November 6, 1996**
Bird recaptured at this location:
Tijeras, New Mexico (35.08ºN 106.37ºW)
Bird recaptured: **December 30, 1996**
Distance between banding & recapture locations:
~25 km (17 miles)
Scaled distance for activity: **~0.25 meters (1 foot)**

16

Bird Species:
Pine Siskin

Bird banded at this location:
Albuquerque, New Mexico (35.13ºN 110.67ºW)
Bird banded on this date: **October 13, 1995**
Bird recaptured at this location:
Tijeras, New Mexico (35ºN 106ºW)
Bird recaptured: **February 1, 1996**
Distance between banding & recapture locations:
~25 km (17 miles)
Scaled distance for activity: **~0.25 meters (1 foot)**

17

Bird Species:
Lesser Goldfinch

Bird banded at this location:
Albuquerque, New Mexico (35.13°N 110.67°W)
Bird banded on this date: **September 30, 1996**
Bird recaptured at this location:
Pojoaque, New Mexico (35.89°N 106.00°W)
Bird recaptured: **August 19, 1998**
Distance between banding & recapture locations:
~100 km (64 miles)
Scaled distance for activity: **~1 meter (3 feet)**

18

Bird Species:
Lesser Goldfinch

Bird banded at this location:
Albuquerque, New Mexico (35.13°N 110.67°W)
Bird banded on this date: **September 6, 1996**
Bird recaptured at this location:
Raton, New Mexico (36.89°N 104.44°W)
Bird recaptured: **August 9, 1998**
Distance between banding & recapture locations:
~275 km (175 miles)
Scaled distance for activity: **~2.75 meters (9 feet)**

19

Bird Species:
American Goldfinch

Bird banded at this location:
Albuquerque, New Mexico (35.13°N 110.67°W)
Bird banded on this date: **January 25, 2003**
Bird recaptured at this location:
West Jordan, Utah (40°N 111°W)
Bird recaptured: **August 16, 2004**
Distance between banding & recapture locations:
~775 km (480 miles)
Scaled distance for activity: **~7.75 meters (25 feet)**

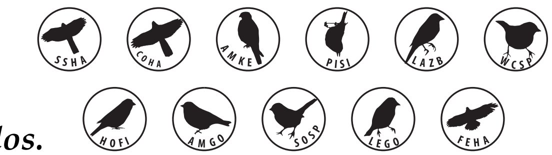
20

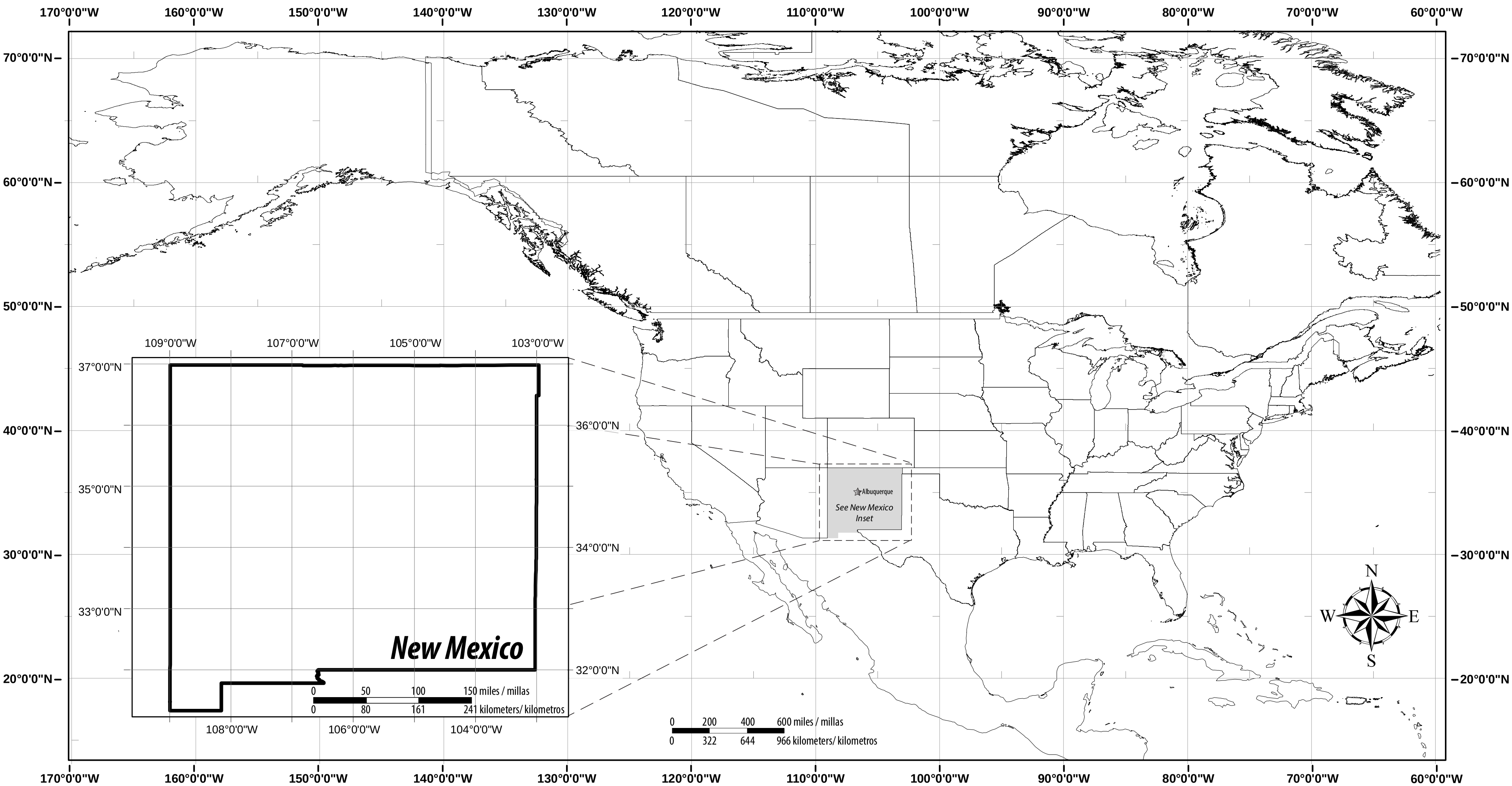
Bird Species:
American Goldfinch

Bird banded at this location:
Albuquerque, New Mexico (35.13°N 110.67°W)
Bird banded on this date: **October 12, 1996**
Bird recaptured at this location:
Heber, Utah (40°N 111°W)
Bird recaptured: **June 15, 1997**
Distance between banding & recapture locations:
~725 km (450 miles)
Scaled distance for activity: **~7.25 meters (24 feet)**

Who Flew Where? ¿Quién voló a dónde?

Add icons of banded recaptured birds to the locations where they were found.
Añadir iconos de aves anilladas recapturadas a los lugares donde fueron encontrados.



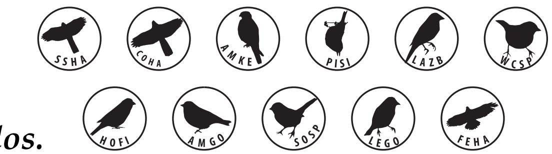


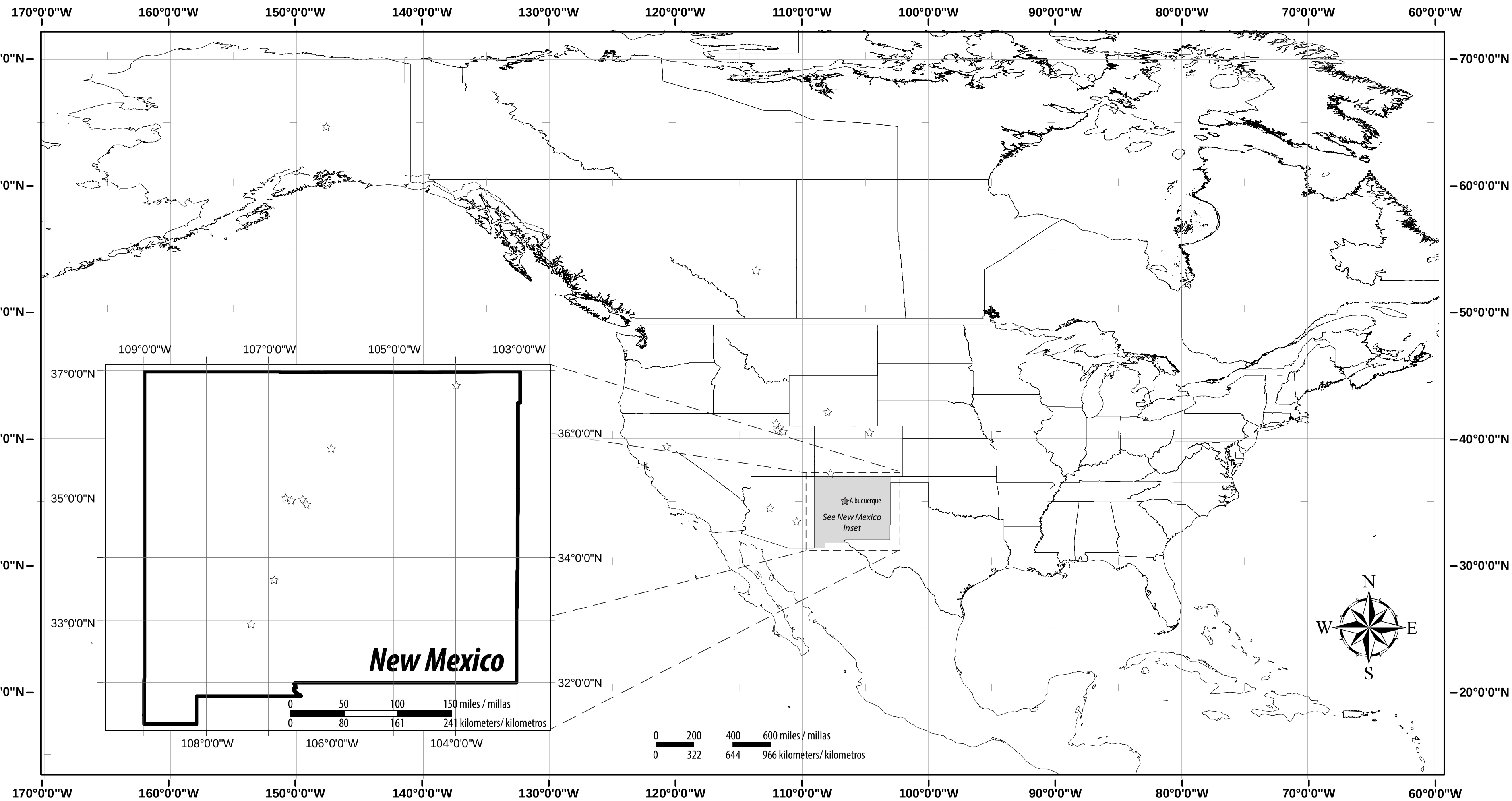
The Bosque Education Guide

Print this page at 11x17. You can download an 11x17 pdf at the New Mexico Museum of Natural History BEG website.

Who Flew Where? ¿Quién voló a dónde?

Add icons of banded recaptured birds to the locations where they were found.
Añadir iconos de aves anilladas recapturadas a los lugares donde fueron encontrados.





The Bosque Education Guide

Print this page at 11x17. You can download an 11x17 pdf at the New Mexico Museum of Natural History BEG website.

48. Changes in Bird Populations

Description: Students graph long-term data of birds banded by Rio Grande Bird Research to see if there have been changes in birds encountered.

Objective: Students look at data, and decide how to present it in graphic form, then write an analysis of the data.

Materials: Graph paper, pencils, worksheets

Background: Look at the main migration background information for Wilson's Warblers, Chipping Sparrows and White-crowned Sparrows.

Procedure: This activity provides total numbers of individuals for three species of birds banded during fall migration by Rio Grande Bird Research at the Rio Grande Nature Center; these are divided into three decades for students to graph.

There is one template that you could use for drawing the graph, or students can start with graph paper and decide on the scale themselves. The vertical axis should be the average number of birds per decade, and both the species of birds and the years (decades) represented should be along the horizontal axis.

- Hand out the raw data and have students calculate averages for three 10 year periods: 1985-1994, 1996-2005, 2006-2015. Note that data for 1995 are missing. Students then make bar graphs for these averages.
- Students should then write a claim-evidence-reasoning statement.

Claim: Answers a question

Evidence: Data that supports the claim. This can be quantitative--numbers you can count; or qualitative--something descriptive such as color.

Reasoning: Explains and justifies why the evidence supports the claim. These should be written in complete sentences.

48. Changes in Bird Populations

Grades: 4-8
Time: one class period
Subjects: area science, math
Standards: see end of activity

Terms: *data, average, bar graph, claim, evidence, reasoning, population*

Rio Grande Bird Research observed that Chipping Sparrows (*Spizella passerina)* were the most commonly banded bird during their first few years of banding. Now, RGBR catches them only rarely. Why? Well, we know that Chipping Sparrows prefer a forest with a closed canopy and we know that many forests have become fragmented. One hypothesis, or possible explanation based on these two statements, is that the Chipping Sparrows numbers have declined because they don't have enough closed canopy any more due to habitat loss. Even though we know that both the earlier statements are true, we don't actually have data to support that one causes the other. Other elements can come into play, such as: drought, fire, flooding, nest success, predation by cats, window strikes, etc.

Chipping Sparrow gathering nesting material in the Sandias
Photograph by Laurel Ladwig

Similarly, it has been observed that Wilson's Warbler (*Cardellinapusilla*) numbers are increasing. They are birds that like "edges" such as the line between where a fire burned and where it didn't, a riverbank, and a fence line. Due to habitat loss, there has been fragmentation and so more edges. Again, it is tempting to say that the increase in Wilson's Warblers numbers is due to the increase in edges. And, again, we don't have enough data to fully support that claim because there are other factors that could be partially or completely responsible.

In the lessons using RGBR data, we have listed possible claims and noted the evidence or data that supports the claims. These claims note what is happening, but do not explain why, because we cannot say "why" based on the data we have so far.

For this activity, here is a possible claim-evidence-reasoning statement.

Claim: Wintering bird populations vary over years

Evidence: From 1985 to 1994 there were an average of 422 Chipping Sparrows banded each year, but an average of 81 were banded each year in 1996 to 2005, and 38 per year from 2006 to 2015. Wilson's Warblers numbers for the same years are, 95, 132 and 145. White-crowned Sparrow numbers were 106, 124, 98.

Reasoning: The Chipping Sparrow numbers dropped dramatically over the decades. The Wilson's Warblers were lower initially, and then almost doubled the following decade, and then dropped somewhat recently. The White-crowned Sparrows (*Zonotrichia leucophrys)* were relatively stable over those years, but still the numbers vary from year to year.

Alternate Claim

Claim: Chipping Sparrow numbers have declined since the 1980s.

Evidence: An average of 422 birds were banded from 1985 to 1994, declined to 81 birds in 1996 to 2005, and 38 birds banded between 2006 and 2015.

Reasoning: Clearly, there are fewer birds being banded in recent years compared to the 1985 to 1994 decade. In fact, the highest number of Chipping Sparrows banded during any year was 1159 birds in 1990, much higher than the average.

Teacher Key:

The average number of birds banded in the years 1985 to 1994:

Chipping Sparrow	422
Wilson's Warbler	95
White-crowned Sparrow	106

The average number of birds banded in the years 1996 to 2005:

Chipping Sparrow	81
Wilson's Warbler	132
White-crowned Sparrow	124

The average number of birds banded in the years 2006 to 2015:

Chipping Sparrow	38
Wilson's Warbler	145
White-crowned Sparrow	98

Assessment:

- Are graphs complete and labeled?
- Does the claim, evidence, reasoning statement make sense, and is written in full sentences that build from one section to the next.

Extensions:

- Students can also graph the following; they should then describe what the graph shows.

  The highest number of Chipping Sparrows banded was 1159 birds in 1990.

  The highest number of White-crowned Sparrows banded was 255 in 1992.

  The highest number of Wilson's Warblers banded was 262 in 2009.

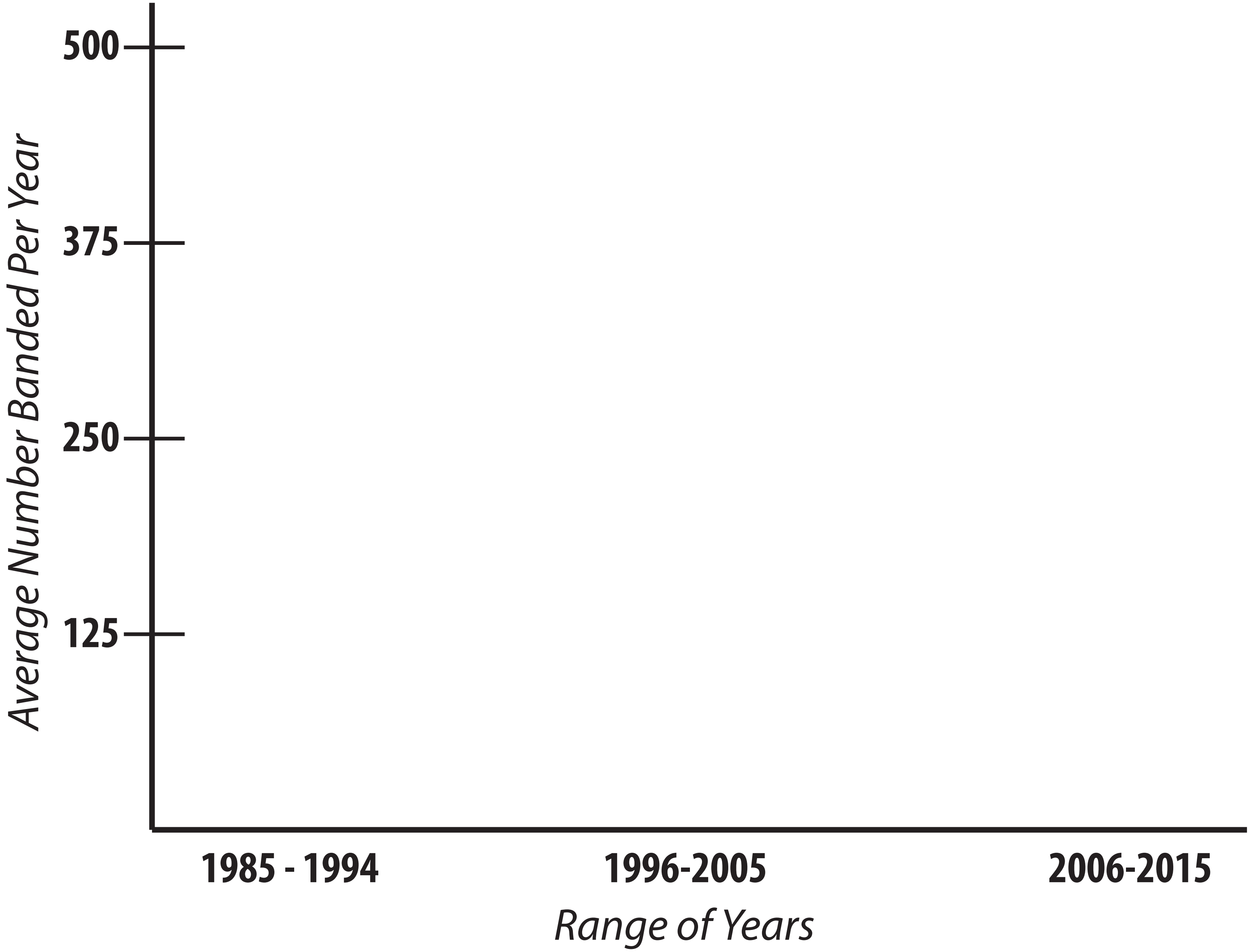
- For more advanced math exercises, calculate error estimates for averages in each of the three decades. How accurately do averages represent actual numbers each year? How much annual variation is present?

Birds Banded at Rio Grande Nature Center 1984-2015

Total numbers of birds captured (banded) during fall migration at Rio Grande Nature Center between 1985 and 2015. Data are included for Chipping Sparrows (CHSP), Wilson's Warblers (WIWA) and White-crowned Sparrows (WCSP).

	CHSP	WIWA	WCSP
1985	304	57	61
1986	159	59	19
1987	114	51	49
1988	88	59	60
1989	244	148	131
1990	1159	139	191
1991	235	124	83
1992	1134	79	255
1993	386	111	114
1994	394	123	101
1995	data unavailable		
1996	272	208	174
1997	78	65	92
1998	21	54	168
1999	46	40	92
2000	12	88	76
2001	185	135	231
2002	27	217	155
2003	118	185	108
2004	2	115	93
2005	47	208	51
2006	61	117	89
2007	168	130	164
2008	17	63	45
2009	73	262	96
2010	8	215	60
2011	14	144	122
2012	8	190	166
2013	12	92	78
2014	13	95	66
2015	6	141	95

Changes in Bird Populations Over Time



A Glossary of Migration Terms

Items with a * are in the glossary for the whole guide, other items are specific to this section.

Adaptation* - a genetically controlled characteristic (anatomical, physiological or behavioral) of an organism that increases its chances of survival and reproduction; also refers to the evolutionary process that creates such a trait

Bosque* (BOH-skay) - Spanish for "woods" or "forest"; in the Southwest it has been used to describe the cottonwood area adjacent to a river (note on pronunciation: use long "o" as in "bow and arrow," otherwise you are actually saying the word "bosky" from old English, an adjective meaning wooded; the English poet Robert Burns once wrote a poem titled "The Bosky Bourne" [the wooded creek])

Climate Change - current patterns in climate data show that our planet's global surface temperature is rising. This change is linked to the dramatic increase in greenhouse gases in the atmosphere that has occurred over the past two centuries. [From the National Oceanic and Atmospheric Administration: http://www.education.noaa.gov/Climate/

Flyway* - the path taken by birds during their annual migrations; many birds will take the same route following a river or mountain ridge as landmarks for their journey

Game bird - a bird hunted for sport or food, or, a member of a large group of birds that includes pheasants, grouse, quails, guineafowl, guans, etc.

Habitat* - the kind of place where an organism usually lives; it includes the arrangement of food, water, shelter and space that is suitable to meet an organism's needs; think of it as the "address" where an organism lives

Migration* - any cyclical movements (usually annual) during the life of an animal at regular intervals and that always include a return trip to where they began

Omnivore* - an animal that eats both plants and animals

Phenology - the study of cyclic and seasonal natural phenomena (such as birds migrating, plants flowering and insects emerging), especially in relation to climate and plant and animal life

Range - the range or distribution of a species is the geographical area within which that species can be found

Riparian* - relating to or living or located on the bank of a natural fresh watercourse such as a river, stream, pond or lake

Sexual dimorphism - the difference in appearance between males and females of the same species, such as in color, shape, size, and structure, that are caused by the inheritance of one or the other sexual pattern in the genetic material

Species* - a unit of classification that refers to a population or series of populations whose members are able to interbreed under natural conditions and do not breed with any other species; for young audiences, an acceptable definition is that a species is a unit of classification that refers to a population (or a group) or a series of populations (or groups) of closely related and similar organisms

Species richness* - the number of species in a community or location

Torpor - a state of decreased physiological activity in an animal which allows the animal to survive cold temperatures or reduced food availability. Animals enter torpor by reducing their metabolisms

Trachea - a large membranous tube reinforced by rings of cartilage, extending from the larynx to the bronchial tubes and conveying air to and from the lungs; the windpipe

Wetland* - a transitional zone between dry land and aquatic (water) areas, which stays wet at least part of the year because the water table is at the surface; includes wet meadows, marshes, sloughs, ponds and small lakes

Zygodactyl - a bird with feet with two toes facing front and two toes facing back

NGSS Connections to Migration Activities – Disciplinary Core Ideas

47 - Who Flew Where?

2.LS4.D Biodiversity and Humans

There are many different kinds of living things in any area, and they exist in different places on land and in water.

PE: 2-LS4-1 *Make observations of plants and animals to compare the diversity of life in different habitats.*

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.

PE: 3-LS4-4 *Make a claim about the merit of a solution to a problem caused when the environment changes and the types of plants and animals that live there may change.*

3.LS4.C Adaptation

For any particular environment, some kinds of organisms survive well, some survive less well, and some cannot survive at all. Particular organisms can survive only in particular environments.

PE: 3-LS4-3 *Construct an argument with evidence that in a particular habitat some organisms can survive well, some survive less well, and some cannot survive at all.*

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.

PE: 4-LS1-1 *Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction.*

MS.LS1.B Growth and Development of Organisms

Animals engage in characteristic behaviors that increase the odds of reproduction

- *How do organisms grow and develop?*

PE: MS-LS1-4 *Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors affect the probability of successful reproduction.*

MS.LS2.A Interdependent Relationships in Ecosystems

-Organisms and populations of organisms, are dependent on their environmental interactions both with other living things and with nonliving factors.

-Growth of organisms and population increases are limited by access to resources.

- *How do organisms interact with the living and nonliving environments to obtain matter and energy?*

PE: MS-LS2-1 *Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.*

MS.LS2.C Ecosystem Dynamics, Functioning and Resilience

Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations.

- *What happens to ecosystems when the environment changes?*

PE: MS-LS2-4 *Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.*

Crosscutting Concepts

Patterns

Cause and Effect: Mechanism and Explanation

Systems and System Models

Science and Engineering Practices

Analyzing and Interpreting Data

Students look at bird banding data, analyze it and make sense of the data.

Developing and Using Models

Students model the migration routes of birds.

Engaging in Argument from Evidence *Construct an argument with evidence, data, and/or a model.*

New Mexico Social Studies Standards

STRAND : Geography

Content Standard II: *Students understand how physical, natural, and cultural processes influence*

where people live, the ways in which people live, and how societies interact with one another and their environments.

K-4 Benchmark II-A: *Understand the concept of location by using and constructing maps,*

globes, and other geographic tools to identify and derive information about people, places, and environments.

Grade 4

1. apply geographic tools of title, grid system, legends, symbols, scale and compass rose to construct and interpret maps;

2. translate geographic information into a variety of formats such as graphs, maps, diagrams and charts;

3. draw conclusions and make generalizations from geographic information and inquiry;

5-8 Benchmark 2-A: *analyze and evaluate the characteristics and purposes of geographic tools, knowledge, skills and perspectives and apply them to explain the past, present and future in terms of patterns, events and issues;*

Grade 5:

1. make and use different kinds of maps, globes, charts and databases;

5. employ fundamental geographic vocabulary (e.g., latitude, longitude, interdependence, accessibility, connections);

7. use spatial organization to communicate information; and

8. identify and locate natural and man-made features of local, regional, state, national and international locales.

Grade 6:

1. identify the location of places using latitude and longitude

5-8 Benchmark 2-C: understand how human behavior impacts man-made and natural environments, recognize past and present results and predict potential changes:

Grade 5

2. identify and define geographic issues and problems from accounts of current events.

Grade 7

2. interpret and analyze geographic information obtained from a variety of sources (e.g., maps, directly witnessed and surveillanced photographic and digital data, personal documents and interviews, symbolic representations - graphs, charts, diagrams, tables, etc.);

4. explain a contemporary issue using geographic knowledge, tools and perspectives.

48 - Changes in Bird Populations

Science and Engineering Practices

Analyzing and Interpreting Data

Engaging in Argument from Evidence *Students write claim, evidence and reasoning statements*

Common Core State Standards Connections

WHST.6-8.1 *Write arguments to support claims with clear reasons and relevant evidence.*

Mathematics

6.SP.B.4 *Summarize numerical data sets in relation to their context.*

References:

Next Generation Science Standards: For States, By States. NGSS Lead States. The National Academies Press. 2013

The NSTA Quick Reference Guide to the NGS: K-12. Ted Willard, editor. NSTA Press. 2015

Geologic History of the Rio Grande Rift

By Jayne Aubele
New Mexico Museum of Natural History & Science

New Mexico is unique in many ways. One of the little-known reasons that it is unique is that it is the site of the Rio Grande Rift which extends from southern Colorado (the San Luis Valley) down the center of our state and into northern Mexico* (see map and diagram on following pages). Much of the landscape, geology, and vegetation of New Mexico is related to the development and location of the rift. The Rio Grande exists because of the rift. Without the rift, there would have been no Rio Grande and no Rio Grande bosque.

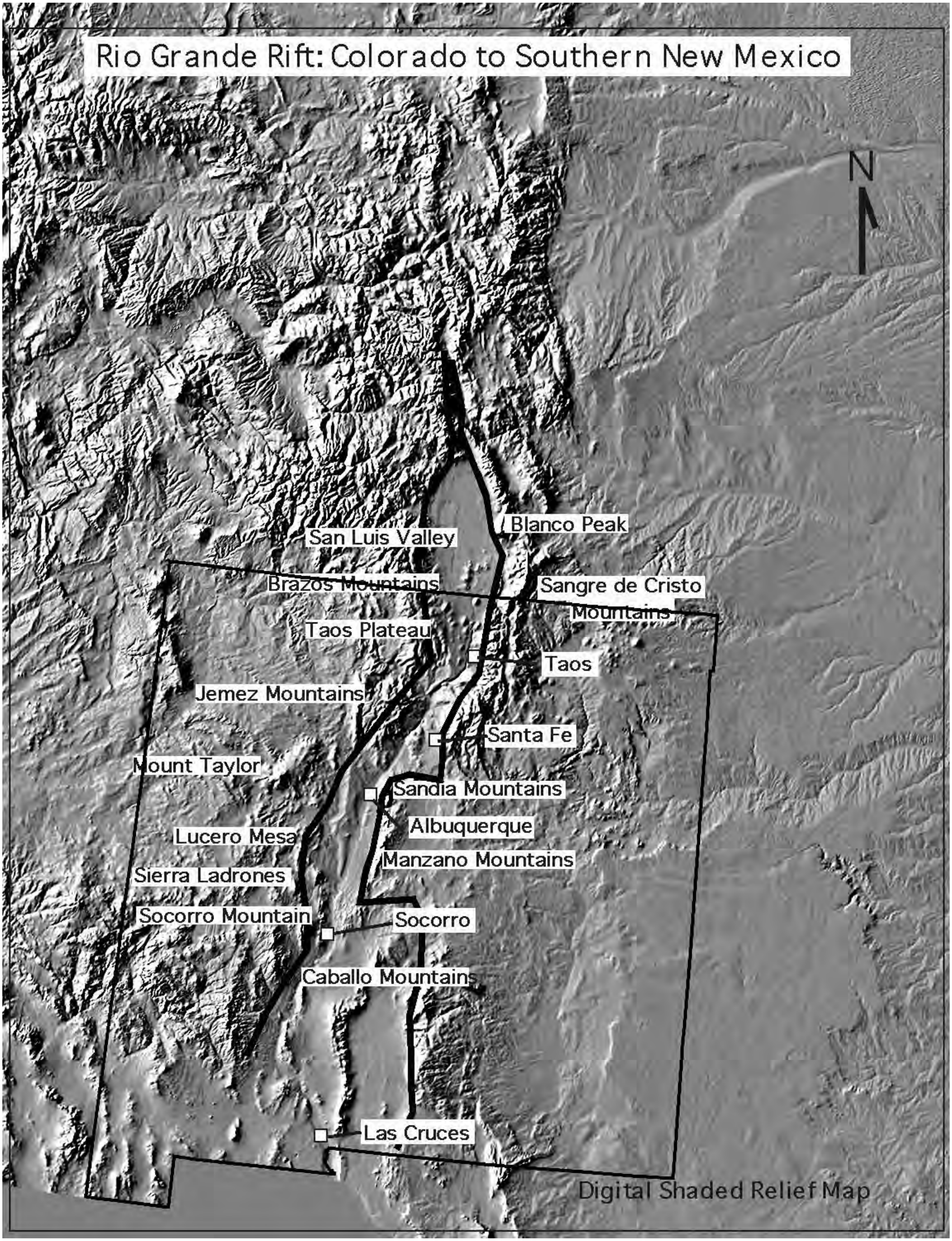
Imagine a New Mexico without the Rio Grande, without the central mountains that today border the Rio Grande on the east, and without the abundant young volcanoes that today parallel the river. This was New Mexico near the end of the Mesozoic Era (65 million years ago [mya]). Streams flowing from west to east carried sediment from western New Mexico onto a flat plain that existed where today Albuquerque and the Sandia Mountains are located. How did New Mexico get from there to here? How did the Rio Grande Rift and the Rio Grande form?

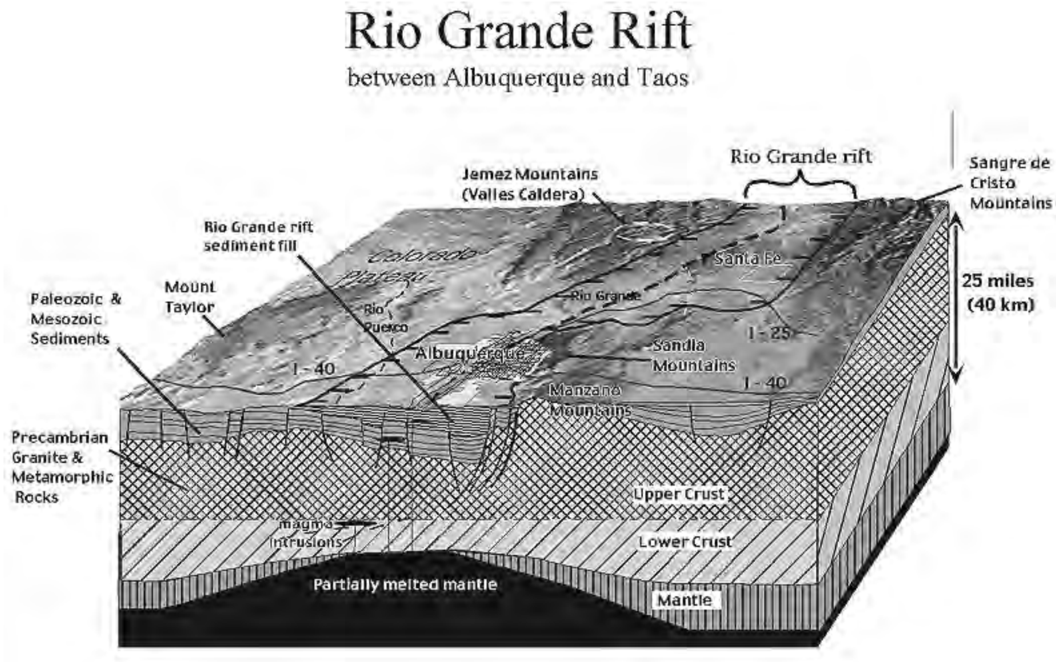
Pushing and Pulling

The Earth's crust is actually made up of many huge, separate pieces; geologists call these plates. Plates cover the Earth much like giant puzzle pieces, but they are not static. They move in relation to each other. Two plates can slide past each other, move toward each other causing mountain building or volcanism, or move apart from each other. New Mexico lies within a single plate, the North American plate, but our state has been affected by the movement of plates far away, along the western edge of the continent.

At the end of the Mesozoic Era, many small plates apparently began to crash into the western margin of the North American plate. These plates caused the continent to ripple like a rug being pushed from the edge. Geologists call this type of movement compression. The "ripples" became the modern Rocky Mountains, extending from Canada into northern New Mexico. The Sangre de Cristo Mountains in New Mexico are the southernmost expression of the modern Rocky Mountains.

* There are only five known young (active or recently active) continental rifts in the world, and the Rio Grande Rift is one of them. A continental rift is a linear area where the crust within a continent is thinning and pulling apart. It is not the boundary of two separate plates, but instead it forms within a plate. It can with time develop into a plate boundary. The other young active continental rifts in the world are: (1) the East African Rift; (2) the Rhine Valley in Germany; (3) the Baikal Rift in Russia; and (4) a recently identified rift beneath the ice in Antarctica.


Rio Grande Rift: Colorado to Southern New Mexico
N
Blanco Peak
San Luis Valley
Brazos Mountains
Sangre de Cristo
Mountains
Taos Plateau
Taos
Jemez Mountains
Santa Fe
Mount Taylor
Sandia Mountains
Albuquerque
Lucero Mesa
Manzano Mountains
Sierra Ladrones
Socorro Mountain
Socorro
Caballo Mountains
Las Cruces
Digital Shaded Relief Map

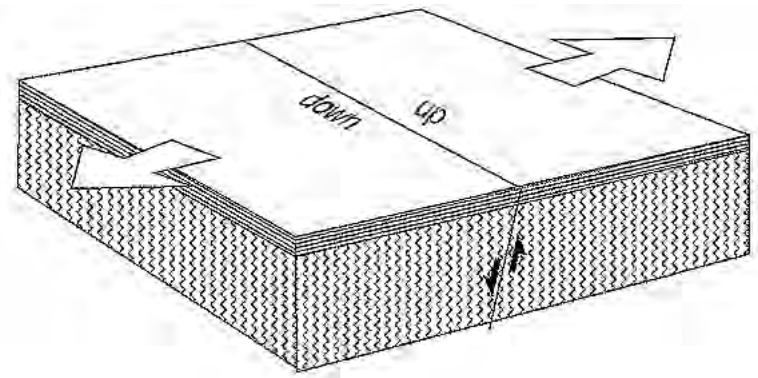


As plates continued to crash into the western edge of the continent, some pieces of plates attached to the edge of the continent. What we now call California was added to this edge. Apparently, at least one plate actually began to move beneath the continent. As this plate traveled from west to east beneath the continent, a wave of volcanic eruptions occurred throughout what would become the western U.S. These volcanic eruptions occurred from 60 to 20 mya and formed the Superstition Mountains in Arizona, the San Juan Mountains in Colorado, and the Mogollon–Black Range–Magdalena–Socorro–Organ Mountain province in New Mexico. Sierra Blanca, the Cerrillos Hills, the Ortiz Mountains, and a volcano that was eventually eroded partially away to form Shiprock also erupted during this time. The "Age of Volcanoes" in New Mexico began during this period and has continued to today.

It's All California's Fault!

About 20 mya something happened to the movement of the North American and Pacific plates. There may have been a redistribution or reorientation of their movements, as occasionally happens, and the compression of the North American continent ended. Instead of pushing the continent into mountainous "ripples," the plate bounding the western edge of the continent began to slide northward along the edge of the continent. This movement continues today and is the cause of the San Andreas fault zone in California. This sliding motion began to tear or pull apart the southwestern region of North America. Geologists call this type of movement tension or shear. As this movement continued, it caused the pulling apart of what is now the southwestern U.S. A series of roughly parallel, north-trending, deep, elongated valleys with intervening mountain ranges were created by this pulling apart of the continent. If you drive through southern Arizona or Nevada today, you see these parallel valleys and mountains in what is called the Basin and Range Province.

During this time, something strange happened in the Four Corners area of northwestern New Mexico, northeastern Arizona, southeastern Utah and southwestern Colorado. This region, which geologists named the Colorado Plateau, was a shallow circular valley during the Mesozoic Era (Triassic, Jurassic, and Cretaceous Periods) and had layer upon layer of rock units deposited on it in a flat layer-cake sequence. At the end of the Mesozoic Era, when the Rocky Mountains were uplifted, and during the Tertiary Period (60–20 mya), when the extensive volcanism was occurring in the western U.S., very little seemed to affect this region. When the continent began to pull apart 20 mya, the Colorado Plateau still was not affected. It stayed as a stable, layered piece of continental crust, while the rest of the continent broke apart into a series of valleys around it. If you pin a piece of paper to a bulletin board with a single pin and then pull on that piece of paper from one direction, the paper will begin to rotate and tear around the pin. That is what happened to the southwestern North American continent. As the continent began to pull apart and rotate around the Colorado Plateau, valleys were created to the south and west of the plateau, and a large valley began to form east of it. This "valley" is the Rio Grande Rift.

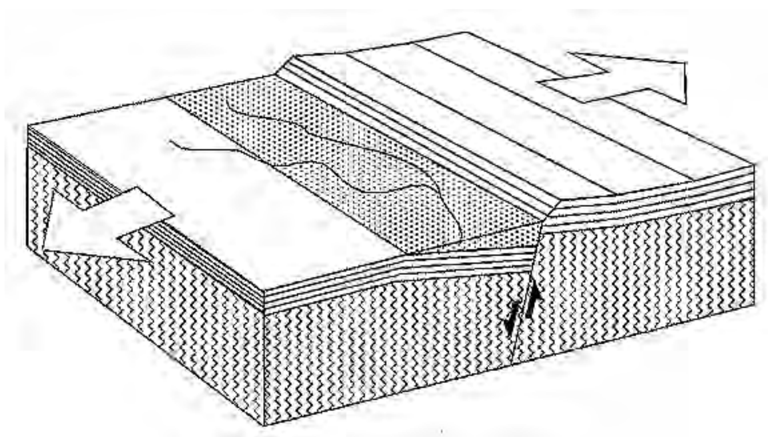


1. Rio Grande Rift 20 million years ago

Like Pizza Dough . . .

A geological rift forms by the pulling apart and thinning of the Earth's crust. You can think about it as though it was pie crust or pizza dough rolled out with a rolling pin and then pulling apart from both sides. If you have ever done this with dough, you know that it does not break in a straight line down the center. Instead, it breaks apart in a series of oval openings that occur as you continue to pull and the dough thins and breaks. This is exactly the way the Earth's crust responds to tension. In fact, the Rio Grande Rift has formed as a series of oval basins or depressions, outlined by faults, that extend in a slightly offset line from southern Colorado to northern Mexico. The escarpment known as La Bajada, between Santa Fe and Albuquerque, forms a margin between two of these basins. The city of Albuquerque was built on top of the eroded debris filling one rift basin to the south of La Bajada, and the city of Santa Fe was built in the basin to the north of La Bajada. A similar situation has occurred just south of Socorro.

As the basins began to form, the continental crust thinned and dropped down to form low areas. Thinner crust meant that it was easier for magma to reach the surface, so volcanoes began to erupt in the center of the rift. Volcanoes from Taos to Carrizozo erupted. In many places, such as west of Albuquerque or Los Lunas, these volcanoes form alignments that are called “fissure vents” where many small volcanoes erupt in a line. In the Albuquerque area, the width of the rift extends from the Sandia Mountains to the Rio Puerco, with the Albuquerque volcanoes right in the center of the rift.



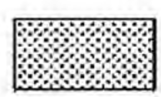
2. Rio Grande Rift 10 million years ago

The series of cracks in the crust at the edges of the rift, called boundary faults, became very complex. Some of the margins of the rift began to be uplifted into the modern central mountains of New Mexico, including the Sandia, Manzano, Manzanita, and Sierras de los Pinos Mountains. The Sandia Mountains near Albuquerque probably began to rise only 5–10 mya, making them geologically young and NOT part of the Rocky Mountains. The Rio Grande Rift and the mountains that form the rift’s margins continue to be geologically active today.

The series of rift basins, with uplifted margins, formed a perfect low area for water to flow. As water runoff began to form in northern mountains, such as the San Juans, the water began to integrate into a permanent through-going river that took advantage of the low area. Most geologists believe that the Rio Grande formed as a major river 1–2 mya. *Most river valleys are eroded or cut by the rivers that flow within them. Unlike most rivers, the ancestral Rio Grande did not erode the broad, flat valley through which it now flows; it simply took advantage of this linked series of basins or low areas.*

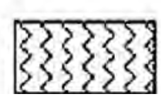
Key to Illustrations

river sediments filling the rift valley (including sand and gravel from the river and eroded from nearby mountains)



sediments from before rift valley formed (including Pennsylvanian limestone)

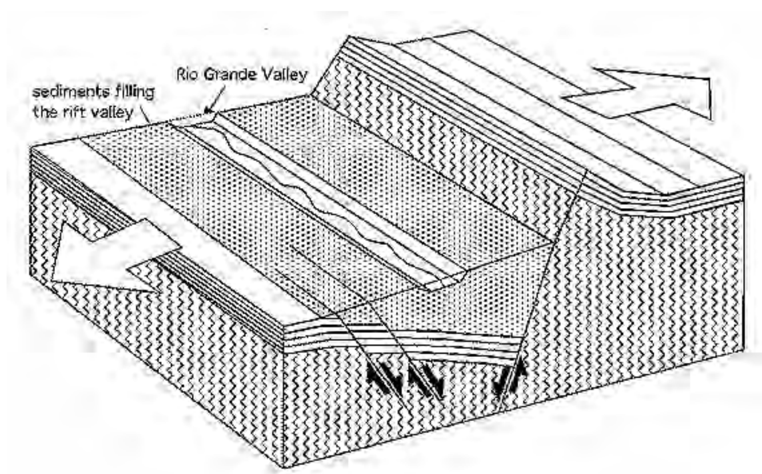
very old rocks (including Precambrian granite)



The modern river, of course, has eroded the small modern channel that you see today. In the Taos area, it eroded the Rio Grande Gorge, cutting down through the layered basalts filling that basin of the rift. Between Los Alamos and Santa Fe, the river cut White Rock Canyon, eroding the 1–3-million-year-old volcanic rocks in that area. Over time, the river channel has migrated and meandered from east to west. At one time the river was as far east as Eubank Boulevard in today's Albuquerque. From Albuquerque south, the river fluctuated between cutting a channel and depositing silt and sand carried down the river. At the end of the last ice age (12,000 years ago) when there was abundant water in the Southwest, the river probably eroded a deeper river channel than we see today. During the past 10,000 years, the river probably deposited material, in general, and actually filled in what was once a deeper, wider river channel. As the modern river flow rate and volume changes, the river bed can be slightly eroded or raised.

The Rio Grande is the Gift of the Rift

In New Mexico, more than in many other places, the landscape is directly related to and produced by dynamic and on-going geology. The rift has provided New Mexico with much of its beautiful landscape, its young mountains and its volcanoes. The rift has also given us the gift of a major river, an unusual phenomenon in our semi-arid southwestern region. As a result, the rift and the river have provided a home for a biologically diverse population of plants and animals, recognized today as the Rio Grande bosque.



3. Rio Grande Rift today

As you can see, the entire history of the Rio Grande is one of change. The river and bosque that we see today are very young, geologically speaking. The Rio Grande Rift is continuing to form. Marginal mountains continue to uplift. Small earthquakes occur within the rift. New volcanoes will someday erupt within the rift. One such place will probably be north of Socorro, where geologists know that molten magma is present beneath the surface, one of only three places in the American continent. For now, the ground is rising a few inches each year over this site. The uplift of the ground is actually causing the river to slow its flow in this area and pond in the Bosque del Apache region. The land and the river keep changing. The story of the Rio Grande Rift, and the river that flows through it, is not yet over.

25. *Time Line Activity*

One way to help students understand the concept of geologic time is to have them make a time line. Using this time line, choose items that are most interesting, with one for each student. Have the students make separate index cards for each one of the items. They can list the item or event and the time when it occurred or they can draw a picture. You then choose a unit of measure for each unit of time. For example, if you choose one centimeter = one million years then the age of the Sandia granite: 1.5 billion = 1,500 million = 1500/100 cm (and million years) per meter = 15 meters of string! If you go back to the beginning of the Earth at 4.6 billion years ago: 4.6 billion = 4,600 million = 4,600/100 cm per meter = 46 meters of string! If you used 1 millimeter for each million years and go back to the formation of the Earth, you will need only 4.6 meters of string.

Have the students stand up with their cards and arrange themselves in order from most recent item or event to oldest. Go down the line and have them state to the class what they are and the time. Then pull out the string and have them measure where they belong on the time line. You can pre-mark the string at each meter/100 million years. The students should then stand at the proper place along the string.

A Few Questions for Discussion

Were the Sandia Mountains here when dinosaurs lived here?
The dinosaurs went extinct 66 million years ago. The rocks that make up the Sandias had been formed, but they did not rise into mountains until 5–7 million years ago.

Are the Albuquerque volcanoes relatively old or relatively young?
They are young in relation to the geologic history of the Earth.

What things do we see together today that formed at very different times?
The Sandia granite and the limestone of the Sandia Crest are next to each other on the mountain, but over a billion years of time is missing.

What happened early in Earth's history? Why have we lost much of the record of it?
There has been erosion and plate tectonic activity to change the surface of the Earth; we have a much better record of more recent events.

Geologic Time Line

ya=years ago; mya=millions of years ago; bya=billions of years ago

Era	Period		
CENOZOIC	QUATERNARY	12,000 ya	oldest known people in North America
		30–40,000 ya	modern humans first evolved: *Homo sapiens*
		150,000–1 mya	Albuquerque and Los Lunas volcanoes erupt; first bison in N. America
		1.1–1.6 mya	San Augustin Plain is a lake; Jemez Mountains (Valles Caldera) erupt
		1.6 mya	
	TERTIARY	1.5–2.5 mya	Rio Grande becomes a flowing stream; first mammoths in North America; Mt. Taylor erupts
		5–7 mya	Sandia/Manzanitas/Manzano/Los Pinos Mountains begin to form
		7–10 mya	Early Jemez Mountain eruptions
		10–20 mya	first bears; Sandias begin to uplift into mountains
		20–30 mya	Rio Grande Rift begins to form; Organ Mountains form; first camels
		35-55 mya	first grasses; first horses; Sierra Blanca erupts
		60 mya	first primates; primitive mammals; Tijeras Canyon fault activated
		65 mya	
MESOZOIC			extinction of dinosaurs, other species at Tertiary–Cretaceous boundary
		67–66 mya	rise and fall of *Tyrannosaurus*
	CRETACEOUS	70–90 mya	rocks formed in Rio Puerco valley; most of New Mexico covered by ocean mosasaur, *Albertosaurus*, *Pentaceratops;*
		100 mya	first flowers; ammonites abundant
		145 mya	
	JURASSIC	150 mya	NM a muddy floodplain (Late Jurassic); first bird, *Archaeopteryx; Stegosaurus, Allosaurus, Camarasaurus, Seismosaurus*
		170 mya	NM a "sand sea" similar to the Sahara (Middle Jurassic),
		200 mya	
	TRIASSIC		*Coelophysis* (NM state fossil); first mammals and dinosaurs; phytosaurs, aetosaurs, *Placerias*
		250 mya	
PALEOZOIC	PERMIAN		*Dimetrodon;* red sandstone deposited in northern NM
		290 mya	
	PENNSYLVANIAN		first reptiles; first seed plants; Crinoids (sea lillies); Madera Limestone (currently Sandia Crest) formed at bottom of ocean covering part of NM
		320 mya	
	MISSISSIPPIAN		shallow reefs cover New Mexico; Crinoids proliferate
		355 mya	
	DEVONIAN		first amphibians
		415 mya	
	SILURIAN		first insects; first land plants and land animals; scorpions
		440 mya	
	ORDOVICIAN		early jawless fishes
		495 mya	
	CAMBRIAN		first fish; trilobites and brachiopods
		545 mya	
PRECAM-BRIAN	PRECAM-BRIAN	1.5–2 bya	formation of granite in Sandia and Sangre de Cristo Mountains
		3.2–3.8 bya	oldest known rocks on Earth; oldest known fossils
		4.6 bya	Earth and other planets in our solar system formed

26. What is the Rio Grande Rift?

Description: Students will learn about the concept of a rift in general and about the Rio Grande Rift in particular. Two different diagrams of the rift can be used by different grade levels or can be used in sequence together for the same grade level. Students color the diagrams, analyze them, and answer in-depth questions about them.

Objectives: Students will:

- understand the geology of the Rio Grande Valley at Albuquerque;
- begin to understand the geological process of rifting and relate that process to the Rio Grande Rift;
- understand that the rock layers exposed in the Sandia Mountains to the east are the same ones over six miles (10 km) below the city; and
- understand that the Rio Grande exists because of the rift.

Materials: three Kleenex® boxes or three medium-sized wood blocks

DiagramA: "Development of the Rio Grande Rift in Three Time Snapshots" (one per student)

Diagram B: "Geologic Cross Section of the Rio Grande Rift at Albuquerque" (one per student)

colored pencils

a photograph of the Sandia Mountains with Rio Grande Valley (postcards work well)

Optional: samples of limestone and pink granite from the Sandia Mountains and a sample of volcanic basalt

Background: See overview explanation in this section, "Geologic History of the Rio Grande Rift."

26. What Is the Rio Grande Rift?

Grades: 3–8 and 6–12

Time: two class periods

Subject: science

Terms: *crystals, fault, granite, layer, magma, rift, sediment, slow-cooling/ fast-cooling, strata, trough, volcano*

The Rio Grande Rift is one of only five young, active continental rifts in the world. The biodiversity and geodiversity of the Rio Grande Valley are related to the existence of the rift. Most river valleys are eroded or cut by the rivers that flow within them. However, the Rio Grande did not erode the broad flat valley through which it now flows; it simply took advantage of the presence of low areas along which to flow.

Diagram A, designed for Grades 3–8, presents simplified snapshots of the area around Albuquerque at different times in the geologic evolution of the landscape. Diagram B (more complete but still simplified), designed for Grades 6–12, is a cross-section drawn on the basis of many pieces of scientific information including drilled wells and geophysical measurements. It is as accurate as it can be at this scale.

Procedure:

1. Introduce the lesson by asking students to talk about the Sandia Mountains, and what they look like, either from their own experience or from viewing a photograph. Ask open-ended questions such as "Do you see different colors?" "Are there different kinds of rock?" "What color are the Sandias as the sun sets?" "Do the Sandias look different when viewed from Albuquerque and when viewed from the East Mountains?" Try to get students to relate as much of their own personal experience of viewing the mountain as possible.
2. Explain that the distinctive look of the Sandias is a result of their geology (both the result of rock type and the result of the way in which they were formed).

   Rock type: As you look at the western side of the Sandias, the bottom three-fourths of the mountain range is mostly made of very old granite. Granite is a rock that is composed of the minerals quartz, feldspar and mica. Granite forms from molten rock deep beneath the surface. The rock cools slowly underground, and the mineral crystals grow to be very big. The pink color at sunset and the eroded rounded appearance of the base of the mountains are both caused by the fact that the mountains here are made of granite. The layered rock at the top of the Sandias is a different kind of rock; it is sedimentary rock, mostly limestone with sandstone and shale. The limestone was formed as a mixture of sediment and fossils at the bottom of an ocean that covered New Mexico about 300 mya. Today the limestone forms the very distinctive layered cap at the top of Sandia Crest.

   In the middle of the rift, associated with the Albuquerque volcanoes, you can find a third type of rock that is very common in New Mexico: basalt. Basalt is a type of volcanic rock that forms when molten rock deep beneath the surface is erupted onto the surface to form a lava flow. Basalt cools very quickly when it reaches the surface and, therefore, the minerals making up the rock are very small and almost invisible without a microscope.

As water and wind eroded the landscape of New Mexico, the river has carried rocks from many areas. If you look closely at the rounded eroded cobbles along today's river channel, which have been carried downstream by the river, you will find granite, limestone, basalt and other rocks from the mountains and volcanoes adjacent to the Rio Grande Rift.

Formation of the mountains: The mountains that form the margin of the rift have been brought up along faults and tilted back, almost like the opening of a trap door. You can see this if you look at the difference between the appearance of the west side and the east side of the Sandias.

3. Demonstrate how the Rio Grande Valley in New Mexico was formed. Place three Kleenex® boxes or blocks of wood together, side-by-side. Then lift all three by holding the two outer boxes—pressing together to raise the middle box as you lift. You have a piece of the Earth's crust with two fault lines (the faults are where the boxes touch each other). Release the tension holding them together, and allow the middle box to drop a few inches, to illustrate the crust dropping in a rift.

   Note: The Rio Grande Rift is not a boundary between two plates; it is a place within the North American plate where the Earth's crust has thinned and dropped downward. Water has followed the low areas of the rift in New Mexico, carrying sand, silt and rocks (products of erosion) along with it over millions of years as the rift formed. Eventually the low areas of the rift were filled with sediment. In the center of the Rio Grande Rift the crust is thin; this becomes the easiest location for magma to come to the surface, such as at the Albuquerque volcanoes.

   Of course, this is a simplified demonstration. In the real situation, the rift would be bounded by many faults on both sides and the rift itself would consist of a series of oval low areas or basins.

4. For younger students, or as an introduction to older students, distribute the time-sequence Diagram A, "Development of the Rio Grande Rift in Three Time Snapshots," and discuss what the area would have looked like if the students could have visited here in a time machine. Are there mountains? How big are they? Was there a river? What direction was it flowing from,

north or west? Where are the volcanoes? Ask students to find and point out these features. Ask students when they would have liked to have lived in the Albuquerque area (20 million years ago [mya], 10 mya, today) and why. Have students color three types of rocks with three different colors:

a. Sandia granite and other rock types around 1.5 bya (billion years ago);
b. the sandstones, shales, and limestones from before the age of dinosaurs and during the age of dinosaurs (350 mya to 65 mya); and
c. the recent sediments filling the rift valley (20 mya to today).

As a group discuss Questions #1, 4, 5, and 6 below.

5. For older or advanced students, introduce the cut-away Diagram B, "Geologic Cross-section of the Rio Grande Rift at Albuquerque" in the student activity pages. Compare the geologic layers to a slice of cake with the levels being different kinds of rock. Ask students to find and point out: 1) the Rio Grande; 2) Albuquerque volcanoes; 3) top of the Sandia Mountains; 4) the largest fault/place of most offset; 5) the magma route to the volcanoes.

   Explain that there are many different types of rocks in the Albuquerque area and that by coloring each layer differently, we will be able to see some of the geologic changes that have happened in this valley.

6. Have students color the diagram and answer the questions.

Questions:

1. Which layer forms the top of the Sandia Mountains and is also buried below the river?
   Pennsylvanian Limestone —300 million years old
2. How many feet/meters of vertical displacement between those two layers?
   40,000 feet/12,400 meters
3. How many feet/meters of vertical displacement are present between the top of the Sandias and the Rio Grande itself?
   5678 feet/1732 meters
4. What happened to the layers of rock that used to be on the top of the Sandias that are still present in the Rio Grande?
   Eroded as the mountains uplifted, the sediments filled in the valleys
5. Which layers have been eroded from the top of the Sandia Mountains?
   Probably all of the Mesozoic units (see overview and geologic time line for more information about Mesozoic)

6. Why are the volcanoes located in the center of the rift?
   Because at the center of the rift, the crust is thinner (again, see overview essay, "Geologic History of the Rio Grande Rift)

Discussion: The colored diagram shows how the layers of rock have dropped down and are off-set in the Middle Rio Grande Valley. Explain that one of the layers of rock in the Albuquerque area was laid down by an ocean that covered this part of North America 300 million years ago; geologists call this Pennsylvanian limestone. This name refers to the time the rock unit was deposited and comes from the state of Pennsylvania, where rocks of this time period were first described. The Pennsylvanian rocks have been faulted in the Rio Grande Rift and are now displaced a great distance. The Pennsylvanian limestone forms the top—horizontal lines seen from Albuquerque—on the crest of the Sandias. The base of the Sandia Mountains contain some of the oldest rock in New Mexico, Sandia granite, which is 1.5 billion years old. The rocks are very old but were pushed up by the rift faults only 5–10 million years ago. Note, the age of the mountains is not the same as the age of the rocks that make up the mountains. (Contrast this to volcanoes where the age of the rock and time of formation are the same.) The Albuquerque volcanoes are very young: about 150,000 years old.

The rift illustrated in the cross-section has dropped deeply on the east side and less on the west. In other areas of New Mexico, the west-side has dropped further. Generally, the rift has large parallel faults, but the center area tips to one side or the other—called a "trap-door" shape, rather than a straight drop down.

Extension/ Assessment: For Grades 3–8, use the techniques described above.

For more advanced middle school students, use the geologic cross-section but have the students color only the Precambrian rocks, Pennsylvania / Permian and the volcanoes. Then have them color the Mesozoic rocks (the age of dinosaurs) and ask them why these rocks are not on top of the Sandias but occur to the east of the Sandias.

Answer: *They either eroded away as the mountains formed or rocks of this age were never deposited in that area. This might happen if it was a high-standing area during this time period.*

Then ask them where the rest of the sediments filling the basin beneath Albuquerque came from.

Sediment that has been eroded off of highlands surrounding the rift or carried down the rift valley by the river.

A few questions for older students:

Find the largest boundary of 'missing time,' between layers. This is the called an unconformity. What might have happened to cause this?

Between the Precambrian and the Pennsylvanian/Permian, either the layers eroded away before 355 million years ago, or the area was high and no material was deposited there.

Look at the faults in the diagram. What type of faults are there? What does this indicate?

They are all normal faults; no thrust or reverse faults are found. This is a signature of a rift valley.

Extension/ Assessment Activity: This activity is a fun evaluation for both younger and older grades. In small groups, students create a model of what they learned from the preceding activity.

Materials for small groups:
- paper and pencils for planning
- cross-section handouts, from this activity, for reference
- plates, trays or pieces of cardboard for the groups to mount their models
- paper for labels
- markers
- plastic knives
- One of the following sets of ingredients:
  - a) cake and icing: un-iced sheet cakes, one per group; frosting containers, one per group, or containers of different colors to be shared by whole group
  - b) peanut butter, jelly and bread for each small group
  - c) Play-Doh® in different colors, one set of at least three colors per small group

Time: two hours

Procedure: 1. Divide class into small groups.

2. After reviewing the rift formation, ask each group to plan how they will show the Rio Grande Rift. They should include the river, layers of rock below the river and the mountains, as well as the steps to form them. Students must identify different parts of the formation with labels. They should refer to their cross-section handouts.

3. Review each group's plans before handing-out one of the above ingredient sets, knives, and labeling paper. Allow students an assembly time of at least 30 minutes to create and label their

models. Encourage groups to add details to them like tiny houses, roads, trees, etc.

4. Have groups describe their model to the class. After the group presentations, plan a time for eating, or, in the case of Playdoh®, baking in the oven for taking home.

Resources/ References: An activity for Grades 6–12 is included in The Watercourse. 2001. Discover a Watershed: The Rio Grande/Rio Bravo. Bozeman, Montana: The Watercourse. "Which Came First the River or the Rift?" p. 195.

What Is the Rio Grande Rift?

Student Questions

1. Which layer forms the top of the Sandia Mountains and is also buried below the river?

2. How many feet/meters of vertical displacement between those two layers?

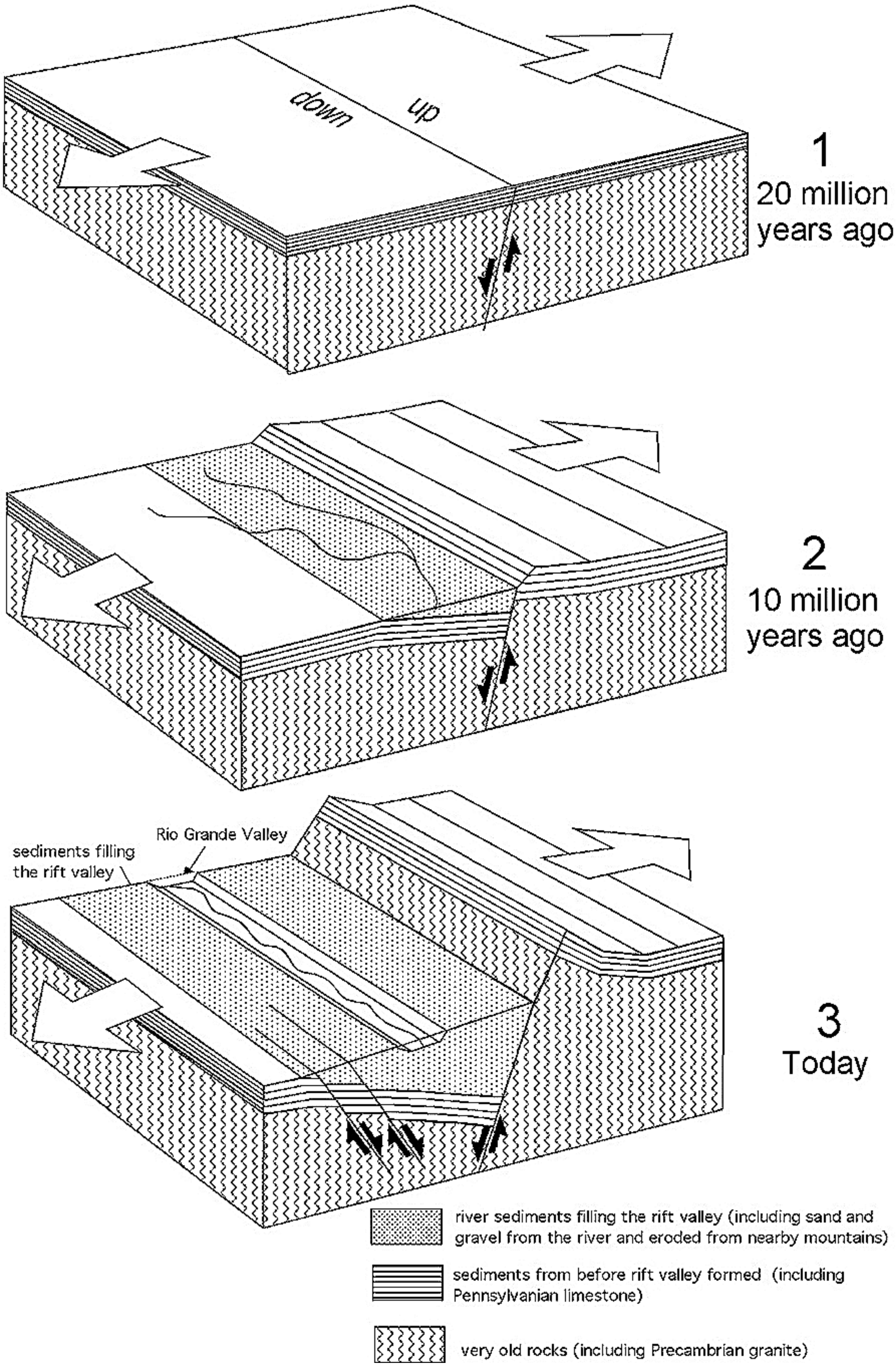
3. How many feet/meters of vertical displacement are present between the top of the Sandias and the Rio Grande?

4. What happened to the layers of rock that used to be on the top of the Sandias that are still present in the Rio Grande?

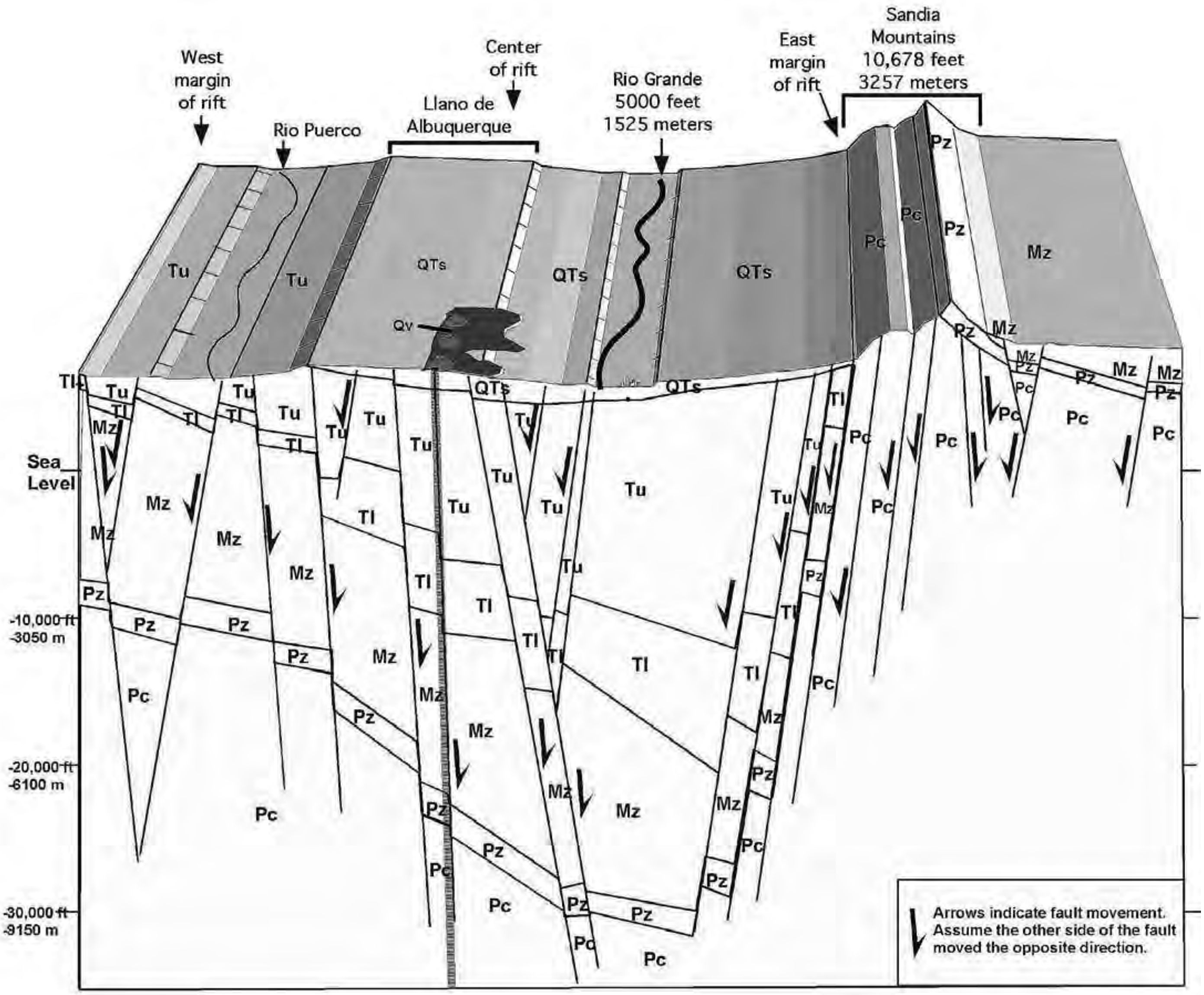
5. Which layers have been eroded from the top of the Sandia Mountains?

6. Why are the volcanoes located in the center of the rift?

A. Development of the Rio Grande Rift in Three Time Snapshots



B. Geologic Cross-section of the Rio Grande Rift at Albuquerque



rock types

Tu	young Tertiary sediments	35 to 2 million years ago
QTs	Tertiary-Quaternary sediments	2 million years ago to present
Qv	Quaternary volcanic rocks	150,000 years ago
Pc	Precambrian rocks	older than 1.5 billion years ago
Pz	Pennsylvanian & Permian sedimentary rocks	355-248 million years ago
Mz	Mesozoic sedimentary rocks	248-65 million years ago
TL	older Tertiary sediments	65-35 million years ago

27. WebQuest: Geologic History

Description: Students work in teams to complete a WebQuest about the geologic history of the Rio Grande and produce a team presentation displaying what they learned.

A WebQuest is a lesson format designed by Bernie Dodge at San Diego State University. This lesson follows that specific format. A WebQuest provides students with a task which can be accomplished using the World Wide Web. Specific web addresses are provided to help guide student research. However, the lesson is loose enough to require students to use research, critical thinking, and synthesis skills to complete the task. Students create a presentation after web research is completed.

Objective: Students will understand:

- that New Mexico is a unique geologic area;
- that the Rio Grande Rift runs north–south through New Mexico and is actively spreading;
- that earthquakes and volcanoes in New Mexico are related to the Rio Grande Rift, as well as other reasons;
- the Rio Grande followed the rift: the river did not cut a valley but rather filled in the rift; and
- the Rio Grande Rift provides the geologic setting for the Rio Grande and the bosque.

Materials: computers with Internet access (minimum one for each team).
PowerPoint, HyperCard, or Netscape or similar software
construction paper
markers, scissors, glue

27. *WebQuest: Geologic History*

Grades: 6–12

Time: preparation: 10 minutes
activity: three or four class periods

Subjects: science

Terms: *Rio Grande Rift, earthquake, earthquake magnitude, volcano, cinder cone, shield volcano, composite volcano, caldera, ash flow, dome volcano, lava flow, aquifer, sediment*

Procedure:

Preparation:

1. Make sure computers are available, working, and connected to the Internet.
2. Assign students to teams of three.
3. Make copies of WebQuest student activity pages.

Doing the activity:

1. Introduce the concept of a WebQuest. Directions are included on the student activity pages.
2. Provide students with a time-line for completing the WebQuest. For example: Day 1–Read the WebQuest and prepare note pages. Day 2–Do web research. Day 3–Do web research. Day 4–Get together as a team and answer "Everyone" questions and design presentation. Day 5–Finish presentation.
3. The teacher should act as a facilitator, helping to trouble-shoot technology problems, asking leading questions, and helping students organize their work. This is a student-centered activity.

Assessment: Presentations—see student activity pages.

Extensions: Have students give oral presentations or show their web or PowerPoint presentations to other students who did not complete the WebQuest.

Teacher Answers to Questions in WebQuest

Volcanologist

1. Why is New Mexico called the Volcano State?
   New Mexico has examples of every type of volcano. New Mexico has a large number, variety, range of preservation, and best examples of volcanoes.
2. What type of volcanoes are in New Mexico?
   Types of volcanoes include cinder cones, stratovolcanoes (composite), shield volcanoes, calderas, ash flows, domes, and lava flows.
3. Why does New Mexico have so many volcanoes?
   The Rio Grande Rift is thinning the crust, making it easy for magma to rise through the crust to the surface.
4. Where will the next volcano likely erupt in New Mexico?
   The next volcano might be near Socorro, New Mexico, where a magma body apparently exists close to the surface.
5. Bonus Question: What other places in the world might be like New Mexico in terms of volcanic structures and activity?
   The mid-ocean ridges, Iceland and East Africa.

Seismologist

1. Does New Mexico have earthquakes? If so, how big are they?
   Yes, New Mexico has earthquakes. Most are fairly small (magnitude 1–3), but some large quakes have occurred in the past century (magnitude 5 –6), and there is evidence of very large earthquakes (magnitude 7) in geologic history.
2. What are some reasons why New Mexico has earthquakes?
   The Rio Grande Rift is still active, rising magma near Socorro, oil and gas drilling, pressure from large bodies of water (Heron and El Vado reservoirs).
3. What causes earthquakes?
   Earthquakes are caused by release of energy in the Earth's crust.
4. Where do earthquakes usually happen? Why?
   Large earthquakes are most concentrated near plate boundaries where tectonic plates are moving relative to each other, but earthquakes can happen anywhere.
5. Bonus Question: What other area of the world might be like New Mexico, in terms of earthquakes, volcanism and general landscape?
   The East Aftrican Rift is much like the Rio Grande Rift, but the East African Rift is actually pulling apart a little faster now than the Rio Grande Rift.

Hydrologist

1. Where did the sediment come from that forms the aquifer?
   The sediment was eroded off the rising Sandia Mountains and other nearby mountains and from volcanoes. The sediment was washed into the Rio Grande Rift and filled up the deep trough.

2. How did this sediment get here?
   Small streams and rivers from the west, as well as the early Rio Grande, washed the sediment into the deep Rio Grande Rift.
3. What did the Rio Grande follow in setting its course?
   The Rio Grande followed the Rio Grande Rift.
4. How is the Rio Grande different from a river that cuts a valley?
   The Rio Grande did not cut its valley. The Rio Grande followed the trough of the Rio Grande Rift. The Rio Grande filled up the rift with sediment instead of cutting down, although it has cut its present-day channel.
5. Bonus: What is wrong with the information given about the size / volume of the aquifer in the Albuquerque Environmental Story page?
   The page says that the aquifer is an underground lake that has large quantities of water. It implies that there is an unlimited supply of water under Albququerque. We now know that drinkable water is limited and we should not take its supply for granted.

Everyone

1. What is the linear feature that the Rio Grande follows that runs north–south through New Mexico?
   The Rio Grande Rift runs north–south and is pulling the crust apart. The center of the Rift is dropped down relative to the sides to form a trough. The trough is mostly filled in with sediment.
2. What is the relationship between this feature and volcanoes, earthquakes, and rivers?
   Earthquakes happen when energy is released from the crust as the rocks in the crust move along a fault. Volcanoes form when magma comes up through the relatively thin crust at the center of the rift. Rivers and streams have filled the trough with sediment. The Rio Grande follows the course of the rift.
3. How did this feature form?
   The Rio Grande Rift is a result of spreading and thinning of the continental crust in this region (see History of the Rio Grande Rift in this chapter). The rift continues to form actively today.

WebQuest: Geologic History

Introduction

Most rivers cut the valley through which they run, but the Rio Grande is very different. We might call it the Rio Grande Valley, but is it really a valley? How did the river get here? The Rio Grande is a unique river in a very unique place.

The Task

You and your teammates need to find answers to the following set of questions. You will use the World Wide Web to research the answers. Once you find the answers, you need to organize the information into an easy-to-follow presentation that explains the geologic history of the Rio Grande. You have a choice of the following options for presenting your answers.

1. Make a poster that has appropriate drawings and information.
2. Make a computer presentation, either as a web-page, PowerPoint slide show or a hyper-studio slide show.
3. Make a picture book.

Each person on your team will have a role and a specific set of questions to research. These are the roles:

Volcanologist: researches the volcanoes of New Mexico and finds out why New Mexico has so many volcanoes.

Seismologist: researches earthquakes in New Mexico and finds out why New Mexico has earthquakes.

Hydrologist: researches the aquifer and the sediments along the Rio Grande and finds out how they were deposited.

Process and Guidance

Each person will use the Internet to answer the questions assigned to her/his role. Follow this procedure.

1. Write down each question that pertains to your role at the top of a separate piece of paper.
2. Visit each web site listed for your role. When you find information that helps answer a question, write down the information on the piece of paper marked with that question. Include drawings. Write down the name of the web site from which you got the information so that you can go back to it if necessary. This part should take two class periods.

3. When everyone is finished researching, each person presents his/her questions and answers to other members of the team. Look for similarities in answers. Answer the "Everyone" questions. You may need to go back to some of the web sites for answers. Begin to put all the answers together to form a story that explains how the Rio Grande was formed and why.
4. Together, choose one of the presentation formats. Design your presentation. Write in your own words and make your own drawings. Do not copy from the web sites. Remember, each team member must contribute text and drawings that pertain to his/her role and questions. Each team member must sign the parts she/he contributed in order to get full credit for the presentation.
5. Grade your other teammembers on a sheet of paper and turn it in (unsigned). Be sure to explain your grade (give examples).
   5 = Team member was easy to work with, did all the work assigned, and was a positive team member.
   4 = Team member did all the work assigned and was mostly a positive team member.
   3 = Team member did all the work assigned but had to be told what to do and how to do it.
   2 = Team member only did some of the work assigned and was not a positive member of the team.
   1 = Team member hardly did anything.
   0 = Team member did nothing.

Questions

Volcanologist

1. Why is New Mexico called the Volcano State?
2. What type of volcanoes are in New Mexico?
3. Why does New Mexico have so many volcanoes?
4. Where will the next volcano likely erupt in New Mexico?
5. Bonus Question: What other places in the world might be like New Mexico in terms of volcanic structures and activity?

Seismologist

1. Does New Mexico have earthquakes? If so, how big are they?
2. What are some reasons why New Mexico has earthquakes?
3. What causes earthquakes?
4. Where do earthquakes usually happen? Why?
5. Bonus question: What other area of the world might be like New Mexico, in terms of earthquakes and plate tectonics?

Hydrologist

1. Where did the sediment come from that forms the aquifer?
2. How did this sediment get here?
3. What did the Rio Grande follow in setting its course?
4. How is the Rio Grande different from a river that cuts a valley?
5. Bonus: What is wrong with the information given about the size/volume of the aquifer in the *Albuquerque Environmental Story* page?

Everyone

1. What is the linear feature that the Rio Grande follows that runs north–south through New Mexico?
2. What is the relationship between this feature and volcanoes, earthquakes, and rivers?
3. How did this feature form?
4. When did this feature form?

Resources

Volcanologist

http://www.nmmnh-abq.mus.nm.us/nmmnh/nmmnh.html
Click on Research and then click on Volcanoes of New Mexico.

http://www.cabq.gov/aes/s1picgeo

Seismologist

http://tremor.nmt.edu

http://pubs.usgs.gov/publications/text/understanding.html
Be sure to read the part about Africa.

http://www.iris.edu
Click on the Seismic Monitor. You should be able to determine where most earthquakes occur.

Hydrologist

http://www.cabq.gov/aes/s1geol.html

http://www.cabq.gov/aes/s1picgeo.html

Assessment

You will receive a team grade and an individual grade. Team grades will be based on the overall completeness and appearance of your presentation. Team grades will also include how well your team worked as a team. Individual grades will be based on your research notes and your contribution to the team.

Team Grade = 40 points
- Completeness: 20 points
  - All questions are answered.
  - Questions are presented in an easy to read/follow format.
  - Information is correct.
  - “Everyone” questions are answered completely and correctly.
- Appearance: 20 points
  - Presentation is neat and pleasing.
  - Presentation includes original pictures and text.
  - Presentation is in easy-to-read format.

Individual Grade = 60 points
- Research Notes: 20 points
  - Each question has a note sheet.
  - Each question shows evidence of research from web sites
  - Each question has proper web site documentation.
- Presentation Answers: 20 points
  - Answers are in original words and pictures.
  - Answers are correct and show understanding.
- Contribution to the Team: 20 points
  - Student contributed fairly and equally to the team.
  - Student contribution to the presentation is signed.
  - Other team members grade your work.

Conclusion

Most people who live in New Mexico do not know why their state is so unique. New Mexico has many geologic features that are unusual and fascinating. Now you can explain some of those features to your neighboring New Mexicans, and you know how and why the Rio Grande formed.

28. Porosity and Permeability

Description: Students test the porosity and permeability of sand, gravel, and clay.

Objectives: Students will understand that:

All grades:

- water is stored underground in the spaces (pores) between grains of sediment; and
- the size of the grains of sediment affects how much water can be stored in the pore spaces.

Grades 5–8:

- the size of the grains of sediment affects how easily water can flow through sediment (permeability);
- sediment and sedimentary rocks that store water constitute an aquifer; and
- porosity and permeability are two characteristics that determine how much water is available in an aquifer.

Materials: Materials are per group of three or four students.

one small graduated cylinder

one dropper

five clear plastic cups—choose clear cups so that students can see the water filling pore spaces

gravel—should be as large as possible and preferably clean

sand—use playground-grade sand only; sand sold and used for mixing with cement (labeled silica sand) has too many fine particles that can harm the respiratory system

28. Porosity and Permeability

Grades: 5–12

Time: material preparation: 15–20 minutes
class time: 30–90 minutes, depending on how many sediment types are tested

Subject: science

Terms: *pore space, porosity, permeability, aquifer, sediment*

clay or very fine soil
sand/gravel mixture
nail
clock or watch with a second hand
four beakers (preferably plastic)
four large containers for holding sediment
four large containers for holding recycled sediment
water

Background: Water is vital to life. More than half of the world's human population uses ground water for survival; but until recently there has been little thought about the problems of depletion or contamination of ground water. More than 20% of the Earth's freshwater resources are in ground water reservoirs; and it is a vital resource, especially in arid areas.

Ground water is present in permeable rocks beneath many land areas; and is a replenishable resource. The problem in arid and semi-arid regions is that the rate of replenishment may be slow or periodic; and the resource can be depleted if ground water withdrawals exceed the local rates of replenishment. This is called ground water "mining." Ground water can actually be dated by the use of radioisotopes. Current work in the Rio Grande Valley indicates that in some areas the ground water we are mining is several thousand years old.

Ground water is created by precipitation. When rain falls, some is absorbed, some runs off into streams and rivers, some evaporates, and the remainder recharges the aquifer. Surface water and ground water are closely related. The water table often represents a reflection of the surface topography, and ground water provides much of the flow in streams and rivers during periods of low rainfall.

When the term ground water is used, many people visualize an underground cavern filled with water. But most ground water occurs in the interconnected pores between rock or sand particles or in fractures in rock. Gravity makes the water connect and flow toward an area where it can be discharged to the surface. Ground water occurs in the ground from the surface to almost 2,000 feet below the land surface and is divided into two zones. The zone where all of the voids in the sand and rock are filled with water is called the saturated zone and the water table marks the top of this zone. Above the water table is the unsaturated zone, where voids in the sand and rock are filled with either air or water.

Layers of rock, sand or gravel that are good ground water reservoirs are called aquifers, from the Latin words for "water" and "to bring." The best aquifers are loose sand and gravel. Sandstone is a good aquifer, while clay, shale and slate are not good aquifers at all. You might be surprised to discover that lava flows can also be good aquifers. The properties that make a good aquifer are those that increase the storage of water (porosity) and increase the flow of water (permeability) within that layer. **Porosity** is the proportion of empty space in a rock. **Permeability** is a measure of the ease with which liquids and gases can pass through a rock. All rocks have pore spaces and fractures; the greater the percentage of pores or fractures and openings in the total volume of the rock, the greater the porosity. In unfractured granite, the porosity may be less than 1%; in loosely consolidated sand and gravel (such as the fill of the Rio Grande Rift), the porosity may be as great as 30%. But it is not enough to have pore spaces; the pores must also be connected so that the ground water can flow. Clay, shale and slate frequently have pores that are not connected and therefore it is difficult for water to enter or leave these rocks. Lava flows frequently have bedding planes and fractures that allow water to flow; springs or seeps are frequently found at the margins of layered lava flows. Fractured granite and metamorphic rock aquifers are the principal sources of water for mountain communities. Because the fractures in these rocks are irregular, the grounwater movement and concentration are also irregular, making exploration for water difficult in these areas.

A type of geologist called a hydrologist studies water resources.

Procedure:

Preparation:

1. Pour sediment into large containers and label accordingly ("sand," "gravel," "sand/gravel," "clay"). Sediment should be dry and free of clumps.
2. Label four more large containers for students to dump used sediment.
3. Using a beaker, determine how much sediment a plastic cup will hold. Write this number on the board. Students must be sure to use the same volume of sediment for each test.
4. Place a beaker in each large container of sediment.
5. Assemble the rest of the lab equipment and divide equipment for each group.

Doing the Activity:

1. Lead a short introductory discussion using the following questions. You may want to write down all student answers on the board. Students can then look back at their answers after the activity to assess how much they learned.

   In New Mexico, where do we get most of our drinking water?

(Students may answer "the river." You should explain that most communities get all or most of their drinking water from underground, although this will change for Albuquerque in 2009.)

From where do the trees and plants get their water? In the bosque, from where do the cottonwoods get their water? How can there be water underground? Where does it come from? How does the water get underground? Have you ever poured water on the soil? Where does it go? How do we (and plants) get the water out of the ground?

2. Develop the questions this lab will examine. Preferably, lead students to develop these questions instead of just giving them the questions. Students may write the questions on their data sheets or in lab notebooks.

   Where is water stored underground?

   Which types of sediment can hold the most water?

   From which types of sediment is it easiest for people and plants to get water?

3. Have students hypothesize answers to the above questions. You may either write group answers on the board or have students write their own hypothesis on their data sheets or lab notebooks.

4. Demonstrate for students how to gather and test each type of sediment. Students will write data on their data sheets or in their lab books.
   a. Use a beaker to fill a plastic cup to the proper volume with gravel.
   b. Fill the graduated cylinder to the top. Record in the table how many ml of water are in the graduated cylinder.
   c. Pour the water SLOWLY into the cup of gravel. Allow the water to soak in all the way. Use the dropper to remove any excess water on top of the gravel. Be sure to put any water removed from the cup back into the graduated cylinder.
   d. Record how many ml of water are now in the graduated cylinder, then discard.
   e. Complete the table to determine how many ml of water you poured into the cup.
   f. Hold the cup of gravel over the extra cup.
   g. Have someone ready to watch the clock.
   h. VERY CAREFULLY, poke a hole at the bottom of the cup with the nail. (Note to teacher: sometimes the gravel you use may have lots of finer sediment mixed in. If you have not washed the gravel, your students will get better results

if they poke the hole on the side of the cup, about 3 cm from the bottom).

i. Time for 30 seconds as the water drips from the first cup into the second cup.
j. Pour the water into the graduated cylinder.
k. Record in the table how much water is in the graduated cylinder.
l. Empty the sediment in the cup into the appropriate container. Do not mix wet (used) sediment with the dry (unused) sediment.
m. Repeat the above steps for the sand, clay, and the sand/gravel mixture. Use small cylinder for clay portion.

Note: The clay trial will take a long time.

5. Compile all class data. Make two charts on the board: one for porosity and the other for permeability. Have each group record their data for sand, gravel, sand/gravel mixture and clay. Calculate the means of each. Graph the means. This will give more accurate results and will illustrate experimental design and replication.

6. Use the following questions to lead a discussion about the data. Alternatively, you may wish to assign these questions for students to answer in written form.

Grades 3–5

a. What is porosity?
b. Which material above held the most water?
c. Why does the mixture of gravel and sand hold less water than either the sand or gravel?
The sand is taking up the spaces between the gravel.
d. What is permeability?
e. Which cup of material would dry out faster? Why?

Grades 6–8: add the following questions

f. What happens to the porosity when the particle size gets smaller?
You should see that porosity increases with smaller particle size. However, with the small volumes tested, the sand and gravel may show similar porosity values.
g. Which material was most permeable? Why?
h. What happens to permeability as particle size gets smaller?

You should see that permeability decreases with smaller particle size.

7. Re-examine the three questions from the beginning of the lab and the hypotheses. Did the data support the hypotheses? Have students develop a conclusion to these questions, based on their data. You may either write a group conclusion on the board or have students write their conclusions on their data sheets or in their lab notebooks.
8. Write the following question on the board. Have students develop an answer either as a group or as individuals.

What type of sediment would make the best aquifer? Why? (Think about which holds the most water AND which material is easiest to get the water out of).

Extensions: Have students bring in a sample of soil from their own home. Measure the porosity and permeability of these samples. Bring in two "mystery" samples to compare with the lab results. Are any results of the "mystery" samples similar to the lab results?

Related Activities: This activity was adapted from similar activities in the following publications:

Gartrell, J. E, Jane Crowder, and Jeffrey Callister. *Earth: The Water Planet*. Arlington, VA: National Science Teachers Association, 1992.

Lind, K. K, (ed). *Water, Stones, & Fossil Bones*. Arlington, VA: National Science Teachers Association, 1991.

Proyecto Futuro, "Earth and Space Science Supplemental Curriculum." New Mexico Museum of Natural History & Science, 1997.

Assessment:

1. Have students draw a picture showing where water is stored underground.
2. Have students explain from where trees and plants get their water.

Thanks to Kristin Gunckel for this activity.

Drawings from the Earth & Space Science Supplemental Curriculum produced by the New Mexico Museum of Natural History & Science.

Porosity and Permeability

1. Use a beaker to fill a plastic cup to the proper volume with gravel.
2. Fill the graduated cylinder to the top. Record in the table how many ml of water are in the graduated cylinder.
3. Pour the water SLOWLY into the cup of gravel until the water reaches the top of the gravel. Allow the water to soak in all the way. Use the dropper to remove any excess water on top of the gravel. Be sure to put any water removed from the cup back into the graduated cylinder.
4. Record in the data table how many ml of water are now in the graduated cylinder.
5. Complete the table to determine how many ml of water you poured into the cup. Pour the water from the graduated cylinder into the sink.
6. Hold the cup of gravel over an extra cup.
7. Have someone ready to watch the clock.
8. VERY CAREFULLY, poke a hole at the bottom of the cup with the nail.
9. Time for 30 seconds as the water drips from the first cup into the second cup.
10. Pour the water from the second cup into the graduated cylinder.
11. Record how much water is in the graduated cylinder in the data table.
12. Empty the sediment in the cup into the appropriate container. Do not mix wet (used) sediment with the dry (unused) sediment.
13. Repeat the above steps for the sand, the sand/gravel mixture and the clay.

    Note: The clay trial will take a long time.

Data Table

	A. beginning ml of water	B. end ml of water	C. ml water used = A - B: porosity	D. ml in cylinder at end	E. ml water dripped out in 30 sec: permeability
gravel					
sand					
sand/gravel					
clay					

29. Rio Grande Bosque Water Cycle

Description: Students roleplay water molecules going through a water cycle.

Objective: Students will understand that:

- water cycles through the Earth and the atmosphere;
- the processes involved in the water cycle include:
  precipitation,
  evaporation,
  runoff,
  transpiration (transpire),
  respiration (respire), and
  condensation;
- in the semi-arid climate of New Mexico, low precipitation amounts limit the quantity of water available for plant, animal, and human use; and
- human users of limited water resources must consider all water users.

Materials:

1. two large buckets, one labeled "Ocean" and the other labeled "Aquifer." Mark a fill line about 1" below the top of the aquifer bucket
2. six bowls with different labels—one each for "River," "Plants and Animals," "Lake," "Agriculture," "Industry," and "Residents"
3. seven paper cups (eight to 12 ounces) to take water from aquifer for agriculture, industry, and residents
4. 18 plastic spoons

29. Rio Grande Bosque Water Cycle

Grades: 3–8

Time: Material preparation: 20 minutes

Class activity: 20-30 minutes

Subjects: science, social studies

Terms: *precipitation, evaporation, runoff, transpiration, respiration, condensation, aquifer, reservoir, ground water*

5. four small (four ounces) paper cups labeled "Clouds"
6. water
7. cards, copied and cut out (from following pages). Laminate them, if possible, since they will be around water.

Feel free to use cups, spoons, etc., that can be reused. Try not to create lots of trash.

Procedure:

Preparation:

1. Label all buckets and bowls.

Note: On small cups (Clouds) mark a fill line at two-thirds of the cup capacity.

2. Copy and cut out game cards on the following pages.
3. Fill Ocean, Aquifer, Plants and Animals, River and Lake containers with water. Spread the containers around the room.
4. Place the Clouds (empty) together in another spot in room. Clouds should be as far as possible from the Ocean container because water moving from the ocean to form clouds in New Mexico must travel a long distance.
5. For Round 2, fill Agriculture, Industry and Residents bowls. During Round 2 these containers will also be placed around the room.

Doing the Activity: *Round 1—Rio Bravo*

1. Pass out game cards and appropriate equipment (spoons or cups). Have each student stand at the first station marked on the card. For example, the student with the "Cloud to River" card stands at the cloud station.
2. Explain the basic procedure. Students will move the water in the containers according to the directions on their card. For example, "River to Lake" moves one spoon of water from the River to the Lake, and returns to the River to take another spoon of water to the Lake. Each student/station continues the activity as directed on their card, if possible, for the time-period of the activity (see 4. below).
3. Announce the following special considerations.

   Clouds cannot dump the water as their card directs until their cups have been filled to the fill line.

   Players taking water from the Aquifer and moving to Plants and Animals may not take water if the water in the Aquifer falls below the marked line.

   The Ocean should never be empty.

If a container is empty, players must wait for water to be added by the appropriate process before they take water from the container.

4. Allow five minutes for students to do their assigned task. Switch cards and repeat the process for five more minutes so students may participate in another part of the cycle.
5. Use the following questions to lead a discussion of the process.

   Why do the clouds wait so long to dump their water?
   Air in New Mexico is very dry. Clouds must gather a lot of moisture before they are able to rain.

   Why are the cloud stations so far from the ocean station?
   New Mexico is a long way from the nearest ocean. Moisture must travel a long distance before it can rain on New Mexico.

   Is there enough water available for the plants and animals? Why is the water below the fill line in the aquifer bucket unavailable to plants and animals?
   This water is too deep to be reached by plants or animals.

   Is there enough water available for the river?
   In an undisturbed system, the plants and animals have adaptations for survival with the amount of water available.

   Where is the most water available for use?
   In the aquifer. The ocean certainly has a lot of water, but it is not available for use by freshwater plants or animals in New Mexico. The ocean is so far away, and it is saline/salty.

   Where is the least water available for use?
   In the clouds.

Round 2—Rio Manso

6. Add Agriculture, Industry, and Residents containers to the set-up. Pass out cards and equipment for Round 2.
7. Repeat the exercise as in Steps 3 and 4.
8. Use the following questions to lead a discussion on the process.

   How was this water cycle round different from Round 1?

   Was there enough water available for plants and animals?

   Why?

   Was there water in the river? Why?

   What do you use water for in and around your home?

   What does agriculture need water for?

How would you make changes to insure that everyone, including residents, agriculture, industry, plants, and animals, has enough water?

Where would pollutants enter into this system and where would they go? What would be affected by pollutants?

To the teacher: This is not a black-and-white easy-to-answer issue. There are many pieces to the problem and very good reasons for what each party wants to do with water. We encourage a discussion about the need for agriculture, industry and communities to use water. Who is allowed to use how much water has been an issue since the first people arrived in this area, with many fights between differing parties. We want students to be able to make responsible decisions about water use in the Southwest.

Extensions: Have students determine their daily water use and suggest what impacts they have on the New Mexico water cycle/water budget. See Project Learning Tree, "Every Drop Counts," or Project WILD, "Water's Going On?!"

Do an "imaginary field trip" through the water cycle. See Project WILD, "Stormy Weather," for general idea.

Related Activities: Project Learning Tree, "Water Wonders."

Assessment:

1. Have students draw a diagram or a picture of the water cycle, from memory.
2. Have students write a story about a water molecule that travels through the water cycle in New Mexico.

Water Cycle Cards

Part 1: Rio Bravo

1.

Cloud to River

small cup

rio bravo 1

2.

Cloud to Plants and Animals

small cup

rio bravo 1

3.

Cloud to Aquifer

small cup

rio bravo 1

4.

Cloud to Lake

small cup

rio bravo 1

5.

River Evaporates to Cloud

plastic spoon

rio bravo 1

6.

Plants and Animals Transpire and Respire to Cloud

plastic spoon

rio bravo 1

7.
Lake Evaporates to Cloud
plastic spoon

8.
Lake Evaporates to Cloud
plastic spoon

9.
Ocean Evaporates to Cloud
plastic spoon

10.
Ocean Evaporates to Cloud
plastic spoon

11.
Aquifer to Plants and Animals
plastic spoon

12.
River to Aquifer
plastic spoon

13.
Aquifer to River
plastic spoon

14.
River to Plants and Animals
plastic spoon

15.
River to Lake
plastic spoon

16.
River to Ocean
plastic spoon

Water Cycle Cards

Part 2: Rio Manso

17.
Aquifer to Agriculture

large cup

18.
Aquifer to Agriculture

large cup

19.
Aquifer to Industry

large cup

20.
Aquifer to Industry

large cup

21.
Aquifer to Residents

large cup

22.
Aquifer to Residents

large cup

23.

Evaporation from Agriculture

large cup

rio manso 2O

24.

Evaporation from Industry to Clouds

large cup

rio manso 2O

25.

Evaporation from Residents to Clouds

plastic spoon

rio manso 2O

26.

Agriculture Runoff to River

plastic spoon

rio manso 2O

27.

Industry Runoff to River

plastic spoon

rio manso 2O

28.

Residents Return to River

plastic spoon

rio manso 2O

30. Surface Water Demonstration

Description: Students observe what happens in a model of a watershed with a plastic-draped surface representing the mountains and spray bottles to simulate precipitation. Students observe and identify how water behaves on the land's surface.

Objective: Students will understand:

- what a watershed is;
- how different land areas (mountains, foothills, valleys, plains) can be part of the same watershed;
- how surface water collects together and flows only downhill; and
- the cohesive property of water.

Materials:

1. large, heavyweight plastic garbage bag, split open, or plastic drop cloth
2. four or more misters (squirt bottles with a fine mist)
3. lunch boxes or backpacks placed under the plastic sheet to make 'mountains'
4. optional: bucket to collect water that drains off the model, and towels to wipe up the inevitable wetness

Background: All the water on our planet is connected via the water cycle (or hydrologic cycle). The water cycle is a water circulation network. (See the "Rio Grande Bosque Water Cycle" activity in this guide.) The water in the Rio Grande is part of the water cycle. This activity explores the surface water part of the water cycle—precipitation and surface water flow.

30. Surface Water Demonstration

Grades: 3–8

Time: Set-up: five minutes; at least 10 minutes to explain, observe, and compare. Add clean up time for spills.

Subject: science

Terms: *precipitate, cohesion, gravity, watershed, surface water, divide, tributary*

The area of land from which water drains into a river is called its watershed. If you imagine that raindrops fall on your school, you might imagine them collecting with other drops and flowing downhill. All of the water that drains into one river system is part of that river's watershed. It is at the high ridges of mountains that the water dropping in one spot may flow east to one river, while a few inches away, the drops flow west ending in a different river system. Your students will set up a model of a mountain and look for the watersheds of their model. This easy, inexpensive model allows observation of what happens in part of the water cycle, how different land areas (mountains, foothills, valleys, plains) can be part of the same watershed, and how surface water collects together and flows only downhill.

Surface water:

collects together *(cohesion)*,
moves only downhill *(gravity)*, and
is used and needed by plants, wildlife, and people.

Procedure:

1. Using a large table, floor or outdoor space, spread the plastic sheet over lunch boxes or other objects forming a 'landscape' with higher mountains on one side or in one corner, some lower hills just below the mountains, and plenty of fairly flat areas. For a table display, arrange the plastic so that water, which collects and flows to the lowest point, will drain off the plastic in one spot where it can be drained into a bucket.
2. Explain that students will be observing behavior of surface water using a model. Ask your students how real land is different than plastic (it has soil, plants, animals, houses, and people). Real land also allows some water to soak into the ground. However, when the spaces in the soil are filled with water, additional water that falls will collect together and flow.

   Things to look for and identify are:

   Water drops—their size, location, and movement.

   Where on this landscape would our school be? (The foothills? The valley?) (Or where on the landscape would be a good place to build a school?)

   Answer these questions through observation: Where does the water come from? Where does the water go?
3. Select several students to be the clouds—the mister operators. The misters must be set on very fine spray. Other participants will be the scientists. Everyone will observe and describe what happens. The clouds should listen for when to precipitate (mist), when to stop, and when to start again. They need to pay attention for directions on where to mist and to be sure

mist falls on all areas of the 'land,' but not on the scientists. Ask the scientists to observe all areas of the land: the mountains, the foothills, the valleys, the plains, and to let us know what happens on all areas. Encourage students to explain their observations using terms such as **gravity** (the force of gravity causes water to move downhill); and **cohesion** (the property of water molecules connecting and pooling). Encourage students to describe everything observed. Much of the precipitation that falls on the landscape will be part of one watershed.

4. Tell the clouds to begin precipitating. Within a few seconds tell the clouds to stop. Ask the observers what they saw the water do. Guide your scientists to describe water falling through the air, tiny drops forming on the surface of the whole landscape—the mountains to the plains. Be sure to observe the entire landscape. Water should not be flowing yet. Focus on observing the drops appear, then grow, then collect.

5. Precipitate (mist) again. Within a few seconds tell the clouds to stop precipitating. What do students notice about the water? Notice the water flowing downhill on the steepest areas. What is happening elsewhere? Water drops are growing larger as more and more water flows downhill. A few puddles are forming. Guide your observers to watch all areas of the landscape.

6. Resume precipitating. Let the clouds keep going and encourage the scientists to describe what they see as it is happening. Direct scientists to report from all areas of the landscape: the precipitation that still makes tiny drops, the drops that still collect together, the movement downhill. Look for movement uphill or over obstacles—it can't happen! The only way for water to spill out of a mountain pond is to keep collecting together until it is higher than the edge of the pond and then overflow. Look for a lake forming in the valley or on the plains. Where is that water coming from? Water flows down from the mountains and also from land near the lake. The clouds continue precipitating until all scientists and observers have had a chance to observe action on all areas of the landscape, and until valley lakes have joined, finding a way to form a river and flow off the plastic. Most of the precipitation will form one main river; some observant scientists will note that the drops on the back of the mountains or on some parts of the flat areas do not flow into the main river, rather, they leak off the side somewhere. This water is part of a different watershed. Precipitation falls everywhere, not just in one watershed at a time. Some water will also move through the watershed as ground water; this is at a much slower rate of movement.

7. Stop precipitating. Share observations.
8. Define the boundaries of the main watershed with your class. Determine ridge tops and areas where the drops collect into the main watershed of the model. Locate land areas where drops form and do not join the main watershed. Guide students to recognize that there are two or more watersheds, depending on where the water flows. Encourage students to review all observations in summary.

Assessment: Depending on the age of students, have them write or draw what might happen to a raindrop.

How are mountain water and valley water connected?

List three things you observed about water on the surface water model.

Define these vocabulary words: precipitate, cohesion, gravity, watershed, surface water, flow.

Extensions: Do the "Watersheds in New Mexico" activity in this guide.

Connecting with the Watershed: Contact a school along another part of the Rio Grande and trade information. Imagine pen pals in another state, or another country, but in the same watershed! What would you like to tell students on a different acequia or arroyo or tributary about your part of the watershed? One school in Albuquerque hosted and gave tours to another local school investigating the bosque. Students can trade photos; monitor the river near their school and post the data; create a field guide to part of the bosque nearest your school or for use on a visit to the Rio Grande Nature Center State Park; visit a school in a different part of town for a tour of how they care for their part of our river.

Students can connect to another stretch of the river. Examples include a high school class from Las Cruces that planned a raft trip near Taos, to experience another reach of their river, and an elementary school in Santa Fe that visited the Rio Grande Nature Center and compared the Rio Grande to their reach of the Santa Fe River.

Mapping Fun: How can we tell if we're in a watershed? Where are we on the map? What map?

You might want to start by making your own map. Imagine a raindrop falling on your schoolyard, joining with other drops and flowing downhill. Where does it go? Is there a tiny arroyo from the canales or gutters of your school building? Does your parking lot drainage lead to an arroyo at the edge of your school grounds?

Does it have a name? Maybe that is as far as you want to draw your first map.

Where does it go from there? Perhaps you would like to get a topographic map including the area of your school. This will show the major arroyos or tributaries near you. How far does your raindrop have to travel to reach the Rio Grande? Locate your country, locate your state, and locate your town on a map. Then get a map of your town, and your part of town. Maybe you want to start with the big picture before you imagine your raindrop. (See "Watersheds" activity in this chapter.)

Watershed Health: How healthy is your section of the Rio Grande watershed?

We all share in the water quality and other resources of our watershed. One way to contribute to the care of our watershed is to collect data and monitor conditions. A **survey** is a collection of measurements, and to **monitor** is to take those measurements over time and compare them. This allows us to notice changes. We can be informed as to the quality of wildlife habitat, drinking water, and pollution issues. Investigate the activity "Kick-net Kritters" (in Chapter 3) for information on how sampling a stream's aquatic macroinvertebrates (water bugs) constitutes a rapid assessment and is an indicator of riparian habitat and water quality.

31. Watersheds in New Mexico

Description: Students will color the different watersheds in the Southwest to learn which rivers drain out of each area of the state/region. *Extensions* include making a pie chart to show the area of each watershed in the state, researching the watersheds in teams and presenting findings about the state's watersheds to the class in a poster presentation.

Objectives: Students will:

- understand the concept of watersheds; and
- be able to identify the watersheds in New Mexico and the Southwest and where they flow.

Materials: colored pencils or highlighters

a copy of the Define Watershed Boundaries worksheet for each student

a copy of the New Mexico Watersheds map for each student

physical map of North America (for finding where New Mexico's rivers flow)

Background: Precipitation that falls to the ground can have one of several things happen to it—it can evaporate, soak into the soil to become ground water, or flow downhill as surface water in rivers and lakes. In this activity, we consider surface water movement as we look at the watersheds of New Mexico. Watersheds are identified by surface water movement. Rivers, streams, creeks, and arroyos are formed where water flows when following gravity. A watershed, or drainage basin, is an area of land drained by a river, river system or other body of water. Except in closed basins, which have no outflow, all watersheds eventually drain into an ocean or sea. Thus you can follow a river from its mouth up to its headwaters, including all of the tributaries that flow into it, to get an idea of the size of the watershed.

31. Watersheds in New Mexico

Grades: 6–8

Time: two class periods

Subjects: science

Terms: *watershed, tributary, Continental Divide, closed basin, headwaters*

It is important for students to understand their place in the watershed. There are plants, animals and people living above them (upstream) and below them (downstream). Things that happen upstream in the upper watershed will flow down to affect them, and things that their community does in the river or drainages of their area will affect plants, animals and people downstream.

New Mexico also contains several closed basins. The water falling in these basins flows down into the basin, but does not flow out to other rivers. Thus, this water does not flow into an ocean. These basins are surrounded by mountains or highlands. The water either soaks into the ground, becoming an aquifer, or pools in surface lakes open to evaporation. In this activity, the closed basins are shaded so as not to confuse students in their search for the boundaries of the major river watersheds.

Terms:

Closed basin: a drainage surrounded by high land without a natural outlet; surface water does *not* flow out to a larger river and thus does not reach the ocean.

Continental Divide: the boundary that separates streams flowing toward the Atlantic or Pacific oceans. Along this divide, water falling within a few feet, such as at a mountain ridge, could flow to different oceans.

Headwaters: the upper reach of a watershed, where the water first collects and begins to flow as a stream.

Tributary: creeks, streams or rivers which feed into a larger stream, river or lake.

Watershed (drainage basin): an area or region drained by a river, river system or other body of water.

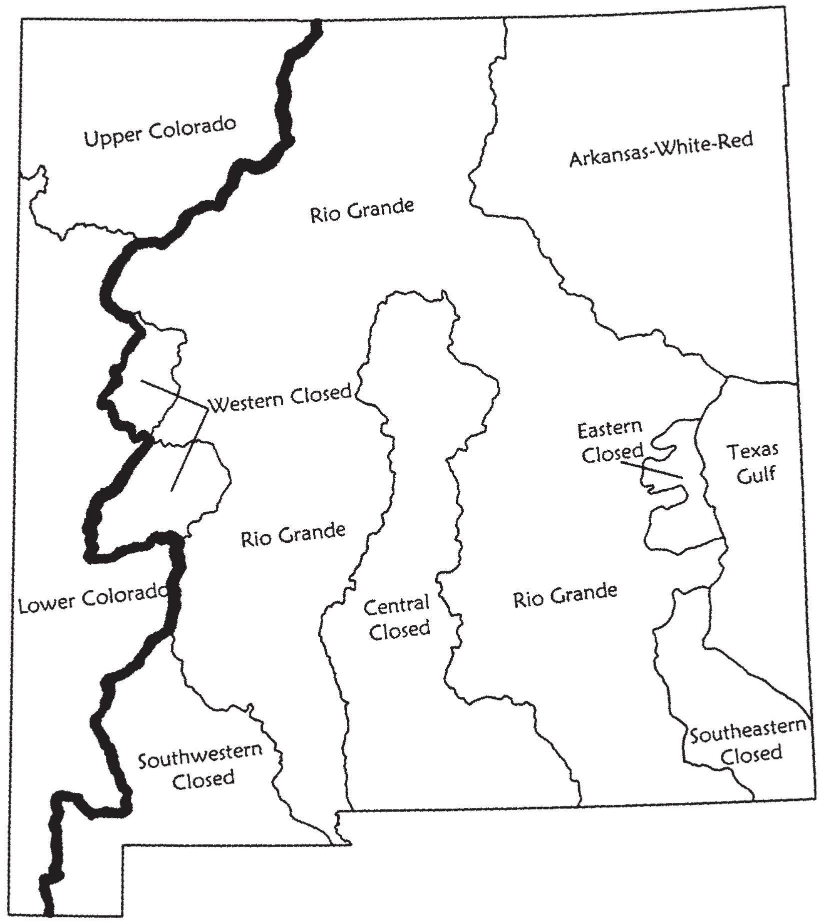
In the activity, the tributaries of the Colorado River are divided into the Upper Colorado Basin and the Lower Colorado Basin. They are all part of the Colorado River Basin, but are considered separately in dividing water for human use. The Glen Canyon Dam near the Arizona–Utah border marks the division.

Procedure:

Introductory questions:

What river do we live near?

Where does our river come from—where are the headwaters of that river? Where does it flow from here—in what direction? Does it flow into a larger river and where does that flow? We are going to look at maps to learn about all of the drainages in New Mexico, called **watersheds**. We will also identify all of the large rivers in New Mexico and where they flow.



River basins and Continental Divide in New Mexico

Do we live in the Atlantic or Pacific watershed? Do you know what the Continental Divide is? The Continental Divide passes right through New Mexico so some of the water that falls in New Mexico goes to the Pacific and some goes to the Atlantic.

Begin the activity: hand out the Define Watershed Boundaries worksheet. Ask students to choose a color of pencil or highlighter marker for each different river system in New Mexico. Begin with the Rio Grande. Start at the bottom of the map with the Rio Grande; begin outside the state boundary and trace upstream. Make sure everyone knows where to begin. Students should trace the main channel of the Rio Grande and all of the tributaries that feed into it with the same color. Color the rivers only at this point. Students must look closely for the sometimes-small space between the upper end of two streams—they almost meet in many locations and in reality only a few feet may separate one watershed from another. (Refer to the "Surface Water Demonstration" activity for a physical model of a watershed.)

After coloring the Rio Grande, color its tributaries in the same color. Then find the rivers below and color them and their tributaries in separate colors:

Pecos
Canadian / Beaver / Cimarron / Arkansas / Frio
San Juan
Little Colorado / Gila / Black

The boundaries of each watershed are between the differently colored river systems. Students can draw a line to divide each color from the other colors, then lightly color the entire area within that divide with the same color as the river. They now have a watershed map.

Use classroom or library resources to link the series of rivers from New Mexico to other rivers and into their respective ocean (the Atlantic / Gulf of Mexico and the Pacific / Sea of Cortez) as shown in the answer key below.

Answer Key:

Rio Grande Basin
Rio Grande—Gulf of Mexico—Atlantic
Pecos River—Rio Grande— Gulf of Mexico—Atlantic

Arkansas-White-Red Basin
Canadian River—Arkansas—Mississippi— Gulf of Mexico—Atlantic
Beaver River—North Canadian—Arkansas—Mississippi— Gulf of Mexico—Atlantic
Cimarron River—Arkansas—Mississippi— Gulf of Mexico—Atlantic

Upper Colorado Basin
San Juan River—Colorado—Sea of Cortez (Gulf of California)—Pacific

Lower Colorado Basin
Little Colorado River—Colorado—Sea of Cortez (Gulf of California)—Pacific
Gila River—Colorado—Sea of Cortez (Gulf of California)—Pacific

Texas Gulf Basin
No major streams are in New Mexico's portion of this basin, so it is shaded already.

Once they have defined the watershed basins of the state, the students can locate the Continental Divide. Ask the students which watersheds flow to the Atlantic and which to the Pacific. The divide is the line where those watersheds meet.
It runs north–south, in the western part of the state. Have them draw the Continental Divide on their map with a different color or type of marker.

Extensions: A. Follow up the mapping activity with the following open-ended questions/discussion.

Major John Wesley Powell was well-known for making the first scientific exploration by boat of the Colorado River through the Grand Canyon. He was politically influential in the late 1800s as a result of his extensive research trips in the western U.S. He maintained in written reports and congressional hearings that the West should be organized by watersheds. New political lines, such as state boundaries, should follow the natural watershed boundaries and not arbitrary lines such as the 37th parallel.

In 1876 Powell wrote: "Nature in its drainage network has indicated the pattern of rational settlement." He further wrote in a report to a special congressional committee, "I early recognized that ultimately these natural features would present conditions which would control the engineering problems of irrigation and which would ultimately control the institutional or legal problems."

What did Major Powell mean when he said this?

How would New Mexico be different if the state boundary followed watershed boundaries?

How does the upper watershed area affect areas downstream?
This can be answered in many ways. For example, ecologically plants and animals travel up and down watersheds. Hydrologically water flows downstream and any pollutants will travel down—what is upstream in terms of pollution possibilities? The volume of water—if too much is used, there won't be much downstream; each year the snow melt causes a flood pulse—the rise in water in the spring brings nutrients, moisture for seed germination, etc; sediment is moved—etc.

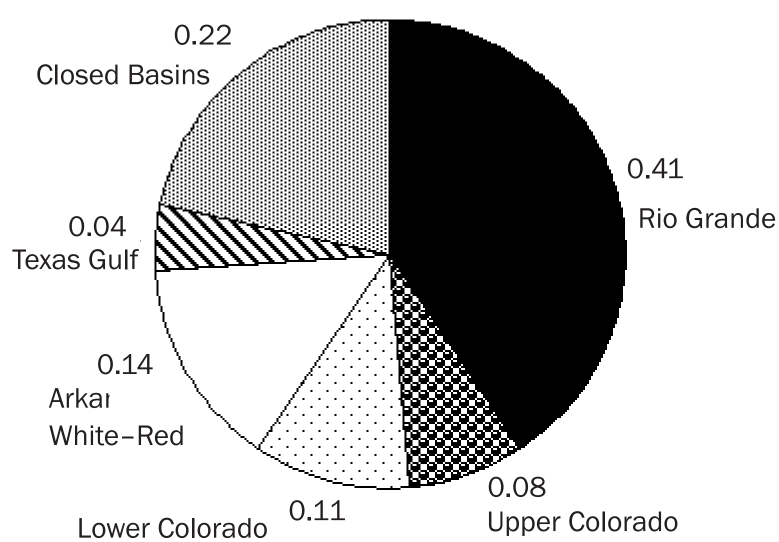
B. Here are the number of square miles and kilometers of the state that are drained by each watershed:

Basin (Watershed)	Square Kilometers	Square Miles
Rio Grande	127,718	49,299
Upper Colorado	25,241	9743
Lower Colorado	34,573	13,345
Arkansas-White-Red	45,539	17,578
Texas Gulf	13,695	5,286
Central closed	30,836	11,903
Eastern closed	3,115	1,202
Western north closed	2,942	1,136
Western south closed	5,136	1,982
Southwest closed	17,071	6,589
Southeast closed	9,002	3,475
Totals	**314,868**	**121,538**

Summary of New Mexico area:
Area NOT a closed basin: 246,766 km^2/95,251 mi^2
Area of closed basins: 68,102 km^2/26,287 mi^2

Make a pie chart to show how much of the state is in each watershed. This is easiest with a computer program.

Ratios of Areas of New Mexico Watersheds and Closed Basins



The entire Rio Grande watershed is 920,389 square kilometers/355,500 square miles. What percent of the watershed is in New Mexico? *18.4%*

The entire length of the Rio Grande is (about) 3033 kilometers/1885 miles (depending on how finely one counts the changing meanders); 752 kilometers/470 miles of it is in New Mexico. What percent of the length is in New Mexico?
Almost 25%; 24.8/24.9% rounded

C. Divide students into teams for each of the watersheds. Have them do a poster on that watershed and present to the entire class. Things to be included: hand-drawn map of the watershed showing at least three communities; descriptions of a watershed boundary, for example: where does it flow to—does it go to the ocean (and which ocean)? Research other statistics—length of each river? What dams if any are on this river? What wildlife refuges, if any, are on or near this river? What major industries are located along the river. What threats are there to the quality of water and natural areas along this river?

D. Discuss the City of Albuquerque's use of San Juan/Chama water for municipal use. This water is already brought from the Colorado watershed into the Rio Grande watershed as part of the Colorado River compact. What do students think about moving water from one watershed to another?

Assessment: The group project (C.) can be a final assessment. Have students draw a free-hand map of New Mexico showing the rivers and watersheds of the state or give them a different map to draw.

Resources/ References

maps (North America, New Mexico and NM Fishing Waters Map)

deBuys, William, ed. 2001. Seeing Things Whole: The Essential John Wesley Powell. Washington: Island Press/Shearwater Books.

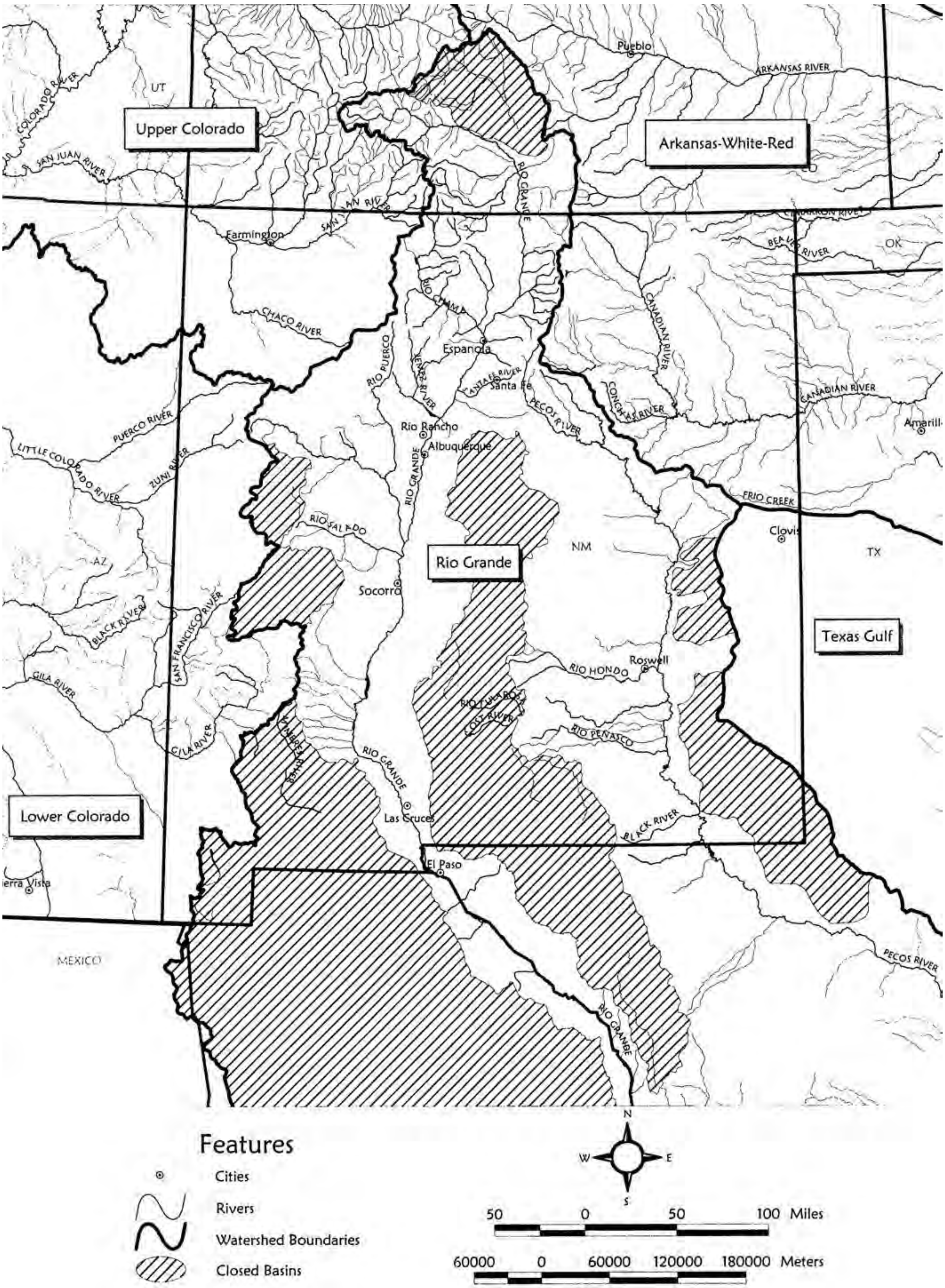
Reisner, Marc. 1986. Cadillac Desert: The American West and Its Disappearing Water. Viking Press, New York, NY (Powell)

Stegner, Wallace. 1954. Beyond the 100th Meridian: John Wesley Powell and the Second Opening of the West. Houghton, Mifflin, Boston.

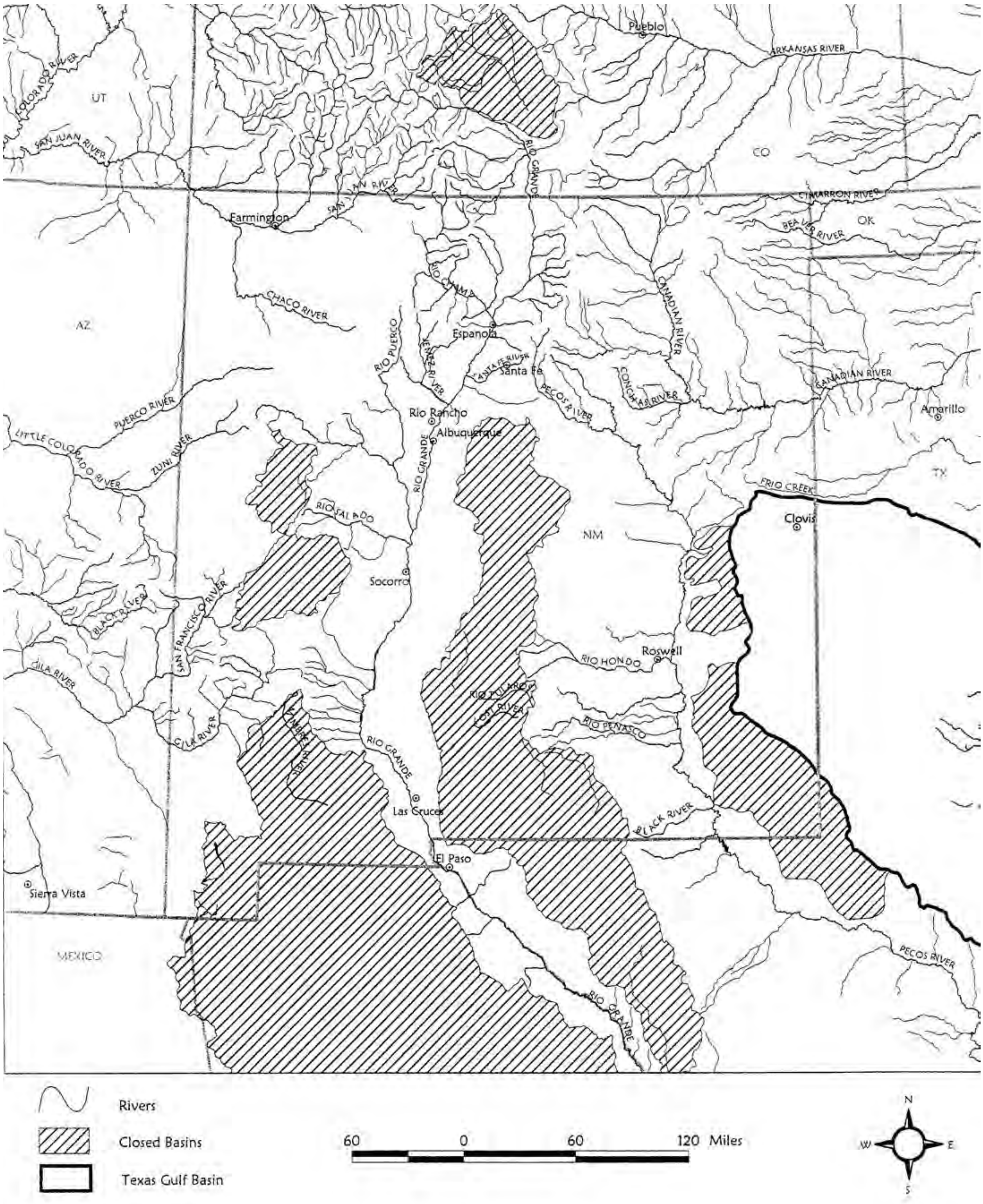
Williams, Jerry L. 1986. New Mexico in Maps. University of New Mexico Press, Albuquerque. "Surface Hydrology" p. 55–57.

"Tributary Tree," p. 201, Discover a Watershed: The Rio Grande/Rio Bravo. Bozeman, MT: The Watercourse. 2001. Background information and additional activity for Grades 6–12.

Teacher Key: New Mexico's Watersheds



New Mexico's Watersheds



Define Watershed Boundaries

Student Worksheet

1. Color these groups of rivers, choosing a different color for each group. Color the boxes next to the river groups below to correspond with how you colored the rivers on your map. Start with the main stem of one river: trace it all the way up, then color all the tributaries for that river system the same color as the river. Then use another color for the next river system, tracing the main stem and the tributaries. Look closely—some streams are very close together, but they belong to different watersheds. Often, they are separated by only a few feet on either side of a mountain ridge. Work your way upstream on each river.

- ☐ Rio Grande
- ☐ Pecos
- ☐ Canadian/Arkansas/Cimarron/Beaver/Frio
- ☐ San Juan
- ☐ Gila/Little Colorado/Black (AZ)

2. Locate the boundaries of the watersheds. Draw a line to show the edges of the watersheds.

Here are some hints to help you draw the boundaries.

A boundary separates different river systems. Look for rivers and tributaries that are almost connected, but not quite.

There are five watersheds in New Mexico.

The Texas Gulf Basin does not have any rivers or tributaries marked on your map. It is already colored for you.

3. Using the same color as the river system, lightly color in the watershed. Don't color the closed basins.

4. Using your map and a map of the United States, trace the path of the following rivers to the ocean; list all of the rivers between each river and the ocean.

Example: Rio Grande→Gulf of Mexico→Atlantic Ocean

Pecos→ ______

Canadian→ ______

Beaver→ ______

Cimarron→ ______

San Juan→ ______

Little Colorado→ ______

Gila→ ______

5. The Rio Grande watershed includes another major New Mexico river. Which river is it?

6. Label the following watersheds on your map:

Arkansas-White-Red Basin

Texas Gulf Basin

Rio Grande Basin

Upper Colorado Basin

Lower Colorado Basin

7. Locate the Continental Divide and draw it on your map with a different color or type of marker. Add that to the map key.

8. Put a star where your community is on the map. List that on the key as well.

32. Rio Grande Stream Table

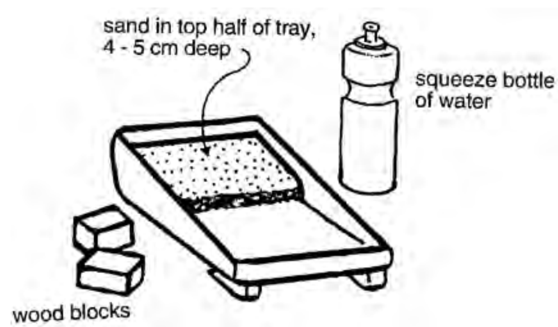
Description: Students will use stream tables to model river processes, especially as they relate to the Rio Grande and the Rio Grande bosque.

Objective: Students will understand that:

- rivers transport sediment;
- rivers shape the land through erosion and deposition;
- the Rio Grande does most of its erosion in the mountains and deposits the sediment along the flatter reaches;
- rivers generally erode on the outside of a meander and deposit sediment along the inside of a meander;
- in the bosque, the inside of a meander is prone to flooding; and
- levees and channelizing of the river have changed the river patterns and processes along the Rio Grande.

Materials: For each student group of three or four students:

paint tray or inexpensive paint tray liners



sand—use playground-grade sand only: sand sold and used for mixing with cement (labeled silica sand), has too many fine particles that can harm the respiratory system.

water bottle or plastic beaker

wood blocks 2" thick

Legos® or Monopoly® pieces to use as houses

paper towels

32. Rio Grande Stream Table

Grades: 3–12

Time: material preparation: 20–30 minutes
class activity: 60–80 minutes, depending on number of trials

Subject: science

Terms: *erosion, deposition, meander, levee, floodplain, sediment, sand bar*

Background:

The landscape of our planet has developed by the interaction of two opposite forces: the force of erosion, wearing away landforms, and the geologic processes that build landforms, generally through volcanism and mountain building. Running water is the most important of the forces of erosion. Year after year, streams and rivers erode and move an enormous amount of rock, sand and gravel from topographically high areas and deposit it in topographically low areas.

The same stream can: 1) carry and transport material that was eroded elsewhere; 2) erode its own channel and banks; and 3) deposit material along its channel and banks. Whether the stream does one or more of these depends on the energy of the stream. This energy, in turn, depends upon the amount of water in the stream and the gradient of the stream channel (the difference in elevation between the beginning and end of the stream).

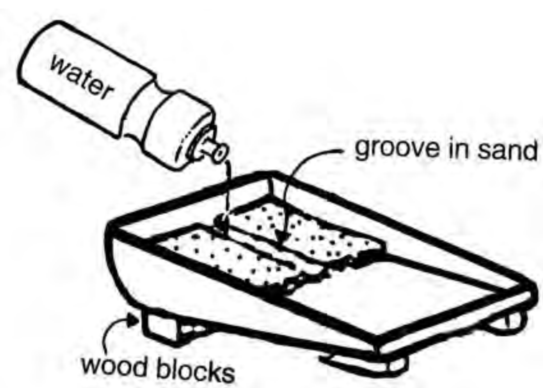
Streams adjust themselves as changes occur in their channel and their gradient and in the velocity of their water. Streams attempt to maintain a constant gradient by increasing or decreasing stream velocity, which affects the deposition or erosion of sediment, which in turn affects the depth and width of the stream channel. As the velocity of the water increases, the size of the material that can be carried by the water and the energy of the stream increase.

Monitoring the volume and velocity of streams is very important in order to understand how much water is available downstream for agriculture, cities, flood control and other uses. The very first river gaging station built by the U.S. Geological Survey in 1889 was in New Mexico, at Embudo Station on the Rio Grande south of Taos.

Procedures:

Preparation:

1. Poke a hole at the bottom (shallow end) of each paint tray for water to drain.
2. Fill each paint tray one-half to three-quarters full with sand. The deep end should be the top and the shallow end should be the bottom. Most of the sand should be in the deep end at the top.



3. At each student work station, place the paint tray on the table with the drain hole hanging just over the edge of the table.
4. Place a bucket on the floor underneath the drain hole in the paint tray to catch water.
5. Divide the rest of the equipment for student groups.

Doing the activity:

1. Begin by asking the following questions. Accept all answers as hypotheses. You may have students write down the question on their data sheets or in a lab notebook.

   "How do rivers shape the land?"

   "How does the Rio Grande shape the bosque?"

2. Demonstrate to students how to use the stream table. Show how to slowly pour water from the beaker or water bottle onto the sand at the top of the paint tray. Demonstrate how the drain hole must be over the bucket.
3. Allow students some time to play with the sand and water. Have students make streams with a finger in the sand and watch what happens as the water flows down the tray.
4. After students have had about 10 minutes to play, have students build the following models. Students should watch each model and note where the river erodes sediment and where it deposits sediment.
   a. Straight river.
   b. Straight river with the top of the paint tray propped up on the wood block (steeper).
   c. Straight river with most of the sediment pushed up to the top of the tray to form mountains at the top and a flat plain toward the bottom. Do not use blocks.
   d. Curving (meandering) river. Be sure to use a broad meander. Do not use blocks.
   e. Rio Grande–Rio Bravo: Push most of the sand to the top of the tray to form mountains and a flat plain toward the bottom. Make a broadly meandering river on the flatter, lower part of the tray.
   f. Rio Grande–Rio Manso, early: Repeat Trial e above but add houses along the river.
   g. Rio Grande–Rio Manso, later: Push most of the sand to the top of the tray to form mountains and a flat plain toward the bottom. Make a straight river on the flatter, lower part of the tray. Build levees next to the river. Add houses outside the levees.

Note: Make sure the students don't dump the sand in the sink at the end of the activity.

5. You may want to have students draw pictures of their river models, using different colors to mark areas of deposition and erosion (examples: red = erosion, green = deposition). Have students describe how each trial is different from the previous trial. You may either ask students questions after each trial or have them describe on their data sheets or in their lab notebooks what happened.

6. Discuss the results using the following questions. You may choose to write answers on the board or have students answer questions on their data sheets or in their lab notebooks.
   a. How did the river pattern change when you put the stream table up on the block? Was there more erosion or deposition? Why?
   There should be more erosion because there is more potential energy for the water to cut into the sediment.
   b. When a river meanders, where does erosion happen (the outside or the inside of the meander)?
   Students should see erosion happening on the outside of the meander.
   c. When a river meanders, where does deposition happen (the outside or the inside of the meander)?
   Students should see deposition happening on the inside of the meander.
   d. How did the river pattern change when you made the mountains and the plain?
   Students should see more erosion in the mountains and more deposition on the plain. This model reflects the modern Rio Grande.
   e. Based on what you know about cottonwood trees, where would new cottonwoods most likely sprout?
   New cottonwood trees would sprout on the inside of meanders where flooding and deposition happens.
   f. What happened to the houses in Rio Bravo Part II (Trial 4.f)?
   g. Did the levees protect your houses any better?
   h. Based on what you know about cottonwood trees and bosques, what would happen to the bosque after the levees were built?
   The river no longer meanders, floods are confined, and cottonwoods would not begin to grow as easily as before the levees.
   i. In Albuquerque, the Rio Grande is actually higher in elevation than the houses in the North Valley. What would happen if we didn't have levees or if the levees broke?

j. Based on what you know about bosques and river processes, what do you think we should do to help the bosque and protect homes and businesses?

Assessment: Have students draw the Rio Bravo and Rio Manso and show, on the drawing, how the river shapes the land and shapes the bosque. Alternatively, students could answer the question in written, paragraph form.

Extensions: During the activity, students may ask questions about "What would happen if . . .?" Allow students to write down their questions and a hypothesis and then test their hypothesis with the model.

Soil Conservation Districts throughout New Mexico have an outreach program where they bring their "Rolling River" trailer to schools. This is a large stream table where the whole class can see river dynamics in action. Call your local Soil Conservation District office to inquire.

Related Activities: This activity was adapted from similar activities in the following publications:

Gartrell, J. E, Jane Crowder, and Jeffrey Callister. Earth: The Water Planet. 1992. Arlington, VA: National Science Teachers Association.

Project Storyline: Science, the Changing Earth. 1993. The California Science Implementation Network, University of California, Irvine.

Proyecto Futuro. Earth and Space Science Supplemental Curriculum. 1997. New Mexico Museum of Natural History and Science.

Thanks to Kristin Gunckel for this activity.

Drawings from the Earth & Space Science Supplemental Curriculum produced by the New Mexico Museum of Natural History & Science.