Collaborative Forest Restoration Program

Monitoring Curriculum

Background and Activities for Ecological Monitoring

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Introduction

This guide was developed specifically for use by schools, teachers, and project leaders involved with ecological monitoring of Collaborative Forest Restoration Program projects. It was designed to provide background information, lessons and activities that relate directly to monitoring goals. It can also be used by other educators interested in teaching students about ecological concepts relevant to the Southwest.

Monitoring Forest Restoration Projects

Southwest forests have changed dramatically in the last century. As people have reduced the number and frequency of fires in the forest, many changes have occurred, including increased density of small trees, changes in species composition, more continuous tree canopies, and the encroachment of trees into meadows. Many of these changes increase the risk of high-intensity wildfires as well as having other ecological effects. The Collaborative Forest Restoration Program (CFRP) was created to bring communities, agencies, environmental groups, and micro-enterprises together to design projects that can restore forest conditions.

> Multiparty Monitoring involves diverse groups of people—individuals, schools, community groups, agencies, and local, regional or national organizations—in assessing changes that come from a project.

Monitoring is an essential part of the Collaborative Forest Restoration Program because it provides reliable feedback on the effects of a project. Monitoring involves repeated measurements over time to determine if actions have caused expected or unexpected changes. As opposed to casual observation, monitoring is designed to help identify changes and determine whether these changes are due to our actions. The information gained from monitoring can help forest managers, scientists, and practitioners learn more about how their projects are working and to adapt treatments or plans along the way so that they better meet project goals. The multiparty process is used because it allows a more diverse group of people to have a say in whether or not a project is having the desired effects. For more information on the multiparty monitoring process, see CFRP Monitoring Handbook 1.

Involving Schools and Youth in Monitoring

The Collaborative Forest Restoration Program also calls for projects to involve young people in some aspect of restoration. Many projects do this by incorporating youth into monitoring efforts. Involving youth in monitoring provides an excellent opportunity for "hands-on," "minds-on" learning, helps develop local stewardship, and plants a seed for long-term involvement and interest in the health of local ecosystems. Through monitoring, youth can learn many aspects of science, including basic forest ecology, observation and measurement skills, problem solving, and how people are currently influencing the forests where they live. These concepts are part of national and state standards for science literacy. Such literacy includes not just the understanding of scientific concepts, but also the role of science in society. Involving students in the monitoring of CFRP projects is an excellent way to achieve both.

What This Guide Is Intended to Do

This guide was developed specifically for use by schools, teachers, and project leaders involved with ecological monitoring of Collaborative Forest Restoration Program projects. It was designed to provide background information, lessons and activities that relate directly to monitoring goals. It can also be used by any educators interested in teaching students about ecological concepts relevant to the Southwest. There are many other relevant resources for educators, particularly the FireWorks curriculum developed by the U.S. Department of Agriculture, Project Learning Tree Environmental Education Activity Guide from the American Forest Foundation, and the Bosque Education Guide, produced by the Rio Grande Nature Center. A list of these and other references and educational resources are included in Appendix 2.

This guide provides background information and classroom and field activities that educators may use with students or youth crews involved in restoration projects. By involving young people in resource management issues, this guide seeks to increase students' understanding of the following:

- Basic principles of forest restoration
- Physical science of forest fires in ponderosa pine forests
- The diversity of plants and animals within an ecosystem
- Natural changes in ecosystems over time
- How people in the past have influenced the ecosystems where they live
- How people are currently trying to influence the ecosystems where they live
- The importance of monitoring any restoration or management effort
- Scientific principles of observation, measurement and evaluation

This guide is organized according to the monitoring goals and indicators of many CFRP projects. An introductory section provides background on these goals. A subsequent section provides activities for the classroom and field. The first several activities provide students with background information and concepts necessary to understand monitoring goals and data. Subsequent activities allow students to gather and interpret data related to monitoring of a specific project. There are also four appendices:

- Appendix 1 gives short activities that can be added to field trips to improve student observation skills
- Appendix 2 provides a list of references and educational resources
- Appendix 3 gives a glossary of terms used throughout the text
- Appendix 4 provides links between activities and educational standards

Integrating School Activities and the CFRP Project

When getting started, teachers, project managers, and others involved with a CFRP project should meet a few times in order to coordinate what will be monitored, when, and by whom. This will help teachers to plan appropriate activities and the timing of their delivery. It also will be helpful for teachers to review CFRP Monitoring Handbook 4, which provides in-depth information about ecological goals and methods to monitor CFRP projects.

Many teachers have difficulty arranging student field trips for more than 1-2 days per year. It should be possible for teachers and CFRP project managers to choose activities that correspond with monitoring goals so that classroom exercises can precede field days. Field trips with a school classroom or education days with a youth crew require advanced preparation and planning. Some things to think about, and sometimes budget for, include:

- Give informational letters to parents prior to any field trip, including items that students will need to bring with them on the day of the trip. This may include sunscreen, hats, long pants and long sleeves, appropriate shoes, and plenty of water. Most youth crews will be accustomed to bringing these items with them each day.
- Arrange transportation to and from the site. Make sure to allow adequate time for travel.
- Arrange for sack lunches from the school for all students, or have youth crews bring their lunch.
- Send out and collect permission slips prior to a school field trip. Bring emergency contacts for students on the field trip.
- Visit the site before bringing any youth to the field so that teachers and others are familiar with the site.
- Prepare all lessons and activities in advance and make adequate copies of any worksheets that may be needed.
- Purchase or collect all equipment that will be used for monitoring and any additional supplies that are required for educational activities.
- Make sure youth understand proper behavior and treatment of the forest before and during the field trip.

Basic Terms & Concepts

There are many terms and concepts that may be new to educators and students alike. Some of these terms are described in the margins of the text. Many other terms are provided in the glossary in Appendix 3 of this guide.

Forest Restoration Background

Ecological restoration is the process of returning more natural conditions to ecosystems that have been damaged by human activities.

CFRP projects are currently underway in ponderosa pine forests, pinyon- juniper woodlands, and bosque systems of New Mexico. These projects can have many goals, depending on the ecosystem and the partners involved in a project. Some goals are specifically oriented toward restoration of forest ecosystems. Other projects seek to reduce the risk of fire hazard to human communities.

In ponderosa pine forests, a primary goal is to reduce the threat of crown fire, the type of intensely hot fire that moves rapidly through the tree tops and causes widespread tree mortality. An equally important goal is to return low-intensity surface fires to these forests. In pinyon-juniper woodlands, most projects focus on reducing the threat of fire to homes and communities. In bosque woodlands, project goals often include removing many non-native species or re-creating historic flood patterns. A summary of common forest types is provided in the table below and in the following pages.

Surface fires typically occur at the ground level of a forest, burning needles, fallen branches, and other fuels on the forest floor.

Surface fires are especially important to restoration because they help reduce conditions such as dense ground fuels and excess young trees that can eventually lead to crown fires.

Ponderosa Pine Forests

Historically, ponderosa pine forests were often comprised of clumps of trees interspersed with small openings or meadows. Since the late 1800s these forests have changed dramatically in the Southwest. Typical ecosystem changes include:

- Decreased cover of grasses and wildflowers
- Shifts in wildlife diversity
- Increased densities of small trees
- Decreased numbers of old and large trees
- Increased old-growth tree mortality rates due to competition from thickets of small trees
- Increased threats of large-scale insect attacks on trees
- Change from low-intensity ground fires to increasingly large, high-intensity "crown" fires
- Increasing threats to property and human lives

Most people agree that these changes are due to drastic changes in land use and land management, particularly fire suppression. Starting in the early 1900s, many small ponderosa pine trees germinated and survived, partly because of the lack of surface fires to thin excess seedlings and partly because of the removal of competition from grass due to overgrazing. As these trees have grown, they have created dense thickets of small trees that typically have little plant cover on the ground. These changes have in turn affected wildlife and fire regimes. Instead of surface fires, most ponderosa pine forests now burn in intense crown fires, which can kill many trees over thousands of acres. While there is no single prescription for every site needing restoration, virtually all ponderosa pine restoration projects involve some tree thinning and reintroduction of surface fires.

A riparian community, or bosque, refers to ecosystems located along streams and rivers and often includes trees such as cottonwoods and willows.

Pinyon-Juniper Woodlands

Pinyon pine and juniper woodlands appear to be changing rapidly in the Southwest in recent decades. Scientists do not understand to what extent this is due to natural causes, such as local climate variability, or to human activities, such as grazing and the suppression of wildfire. The history of fire in pinyon-juniper woodlands is also not well understood. However, many people now live in areas of dense pinyon-juniper woodlands that pose a serious fire hazard to homes and villages. People are therefore treating pinyon-juniper woodlands in areas that could threaten human communities. Treatments usually involve reducing tree densities by thinning in order to reduce this risk of destructive fire.

Non-native plants are those that come from a different ecosystem than where they are currently growing.

Riparian Communities

Southwestern riparian communities have been changed by human activities over a long period of time. Much of the Rio Grande valley has been inhabited by indigenous people for more than a millennium, and Hispanic uses, including livestock grazing, have been important for centuries. In New Mexico, a riparian community is often called a bosque, a Spanish word for woodlands. Some ecosystem changes seen in riparian communities include:

- Lowered water table
- Soil erosion and unstable river banks
- Increased numbers of non-native plant species
- Decreased numbers of native plant species, especially cottonwood trees
- Increased number of jacks, levies, and other flood-control structures that straighten the river
- Reduced flooding over the banks of the river
- Increased fire hazard
- Reduced soil moisture

Table 1. Summary of different forest types in CFRP projects

Forest Type	Bosque woodlands	Pinyon-juniper woodlands	Ponderosa pine
Elevation	Along floodplains of major rivers	5000-6500 feet	6500-8000 feet
Historic fire frequency	Rare. Reduced natural flooding and increase of non-native species have resulted in recent catastrophic fires in this system	Uncertain. Probably stand replacing fires, in places at intervals of 100-200 years	Surface fires, every 5-30 yrs Crown fires, very infrequent
Traits for surviving or reproducing well after fire	Not adapted	Not adapted	Open forest Thick buds Thick bark Open, high crown
Disturbances besides fire	Flooding	Dwarf mistletoe Bark beetle	Dwarf mistletoe Bark beetle
Common CFRP goals	Removing non-native tree species. Recreating historic flood patterns	Reducing threat of fire near homes and communities	Decreasing threat of crown fires. Returning low-intensity surface fires
Some native animals	Tree swallow Sharp-shinned hawk Belted kingfisher Summer tanager Greater roadrunner Beaver Little brown bat Tiger salamander	Pinyon jay Western scrub jay Blue-gray-gnatcatcher Rock wren Red-tailed hawk Collared lizard Jackrabbit Coyote	Steller's jay Pygmy nuthatch Western bluebird Dark-eyed junco Tassel-eared (Abert) squirrel Black bear Mule deer
Some native plants (trees, shrubs, herbaceous plants)	Cottonwood species Willow species New Mexico olive False indigo Yerba mansa Common horsetail Sedge species	Pinyon pine Juniper species Chamisa (rabbit brush) Snakeweed	Ponderosa pine Quaking aspen Gambel oak Mountain mahogany Blue gramma grass Wild geranium Penstemon species Wood violet

Traditional approaches to restoration are not useful for riparian community restoration in New Mexico. Typical restoration involves referring to sites that have been and continue to be relatively free from recent human disturbances. Because all riparian areas in New Mexico have been influenced by humans for many centuries, there are no such relatively unchanged sites. However, most lowland riparian communities were probably mosaics of the following:

- Areas of young cottonwood, willow, and native olive trees
- Forests with mature cottonwood trees
- Wet meadows, open marshes, ponds, and grasslands

Because there are no relatively natural bosques to use as models, restoration of these systems frequently involves efforts to restore natural processes. For example, a natural cycle of flooding over river banks allows cottonwood seeds to germinate. But restoring natural water flows is very difficult. A more practical restoration approach is the removal of non-native trees, such as Russian olives. This reduces the threat of fires, which can be devastating to native tree populations in the bosque.

Table 2. Restoration goals and related curricular activities

Restoration Goal	Activities
Change fire regimes	Determining Reference Conditions Understanding Forest Fires The Fire Triangle in Wildlands Bucket Brigade Dendrochronology Detectives Burned Area Scavenger Hunt Tree ID/Size Structure What's Growing Up?
Preserve old and large trees	Determining Reference Conditions Who Lives Here? Dendrochronology Detectives Tree ID/Size Structure
Enhance native plants/reduce non-native plants	Determining Reference Conditions Understanding Forest Fires Who Lives Here? Compaction Action What's Growing Up?
Conserve wildlife populations and habitats	Who Lives Here? For the Birds Bosque Boogie What's Growing Up?
Conserve soil resources	Who Lives Here? Compaction Action
Conserve and protect riparian communities	Determining Reference Conditions What's in a Watershed? Who Lives Here? For the Birds Bosque Boogie Tree ID/Size Structure

Restoration Goals

A restoration goal is a general summary of the desired state a project is trying to achieve. Most CFRP projects are trying to address one or more of the following goals:

1. Change fire regimes
2. Preserve old and large trees
3. Enhance native plant populations and reduce invasive, non-native plant populations
4. Conserve wildlife populations and habitats
5. Conserve soil resources
6. Conserve and protect riparian communities

Monitoring goals usually relate to the overall restoration goals of a project. Table 2 and the text that follows list each of these goals and curricular activities that will give students a broader understanding of concepts that relate to these goals.

Goal 1: Change fire regimes

A primary goal of restoration in ponderosa pine forests is to reduce the threat of crown fire. An equally important goal of restoration is to re-establish low-intensity surface fires that burn across the forest floor. These surface fires are important because they help maintain a lower level of ground fuels and fewer excess small diameter trees. Without reintroduction of these surface fires, many of the positive ecological changes brought about by various treatments will be short-lived. Low-intensity fire can be returned through prescribed burning or allowing natural fires to burn when circumstances allow this. In riparian communities and pinyon-juniper woodlands near towns, no such return of fires is needed. The following activities will provide students with a better understanding of fire ecology in ponderosa pine forests.

- Determining Reference Conditions
- Understanding Forest Fires
- The Fire Triangle in Wildlands
- Bucket Brigade
- Dendrochronology Detectives
- Burned Area Scavenger Hunt
- Tree ID/Size Structure
- What's Growing Up?

Goal 2: Preserve old and large trees

Old and large trees have significant ecological value for many reasons. Due to logging, overgrazing, and fire suppression, large old trees are no longer common in southwestern forests, so it is important to preserve those that do exist. Large trees, both living and dead, are important for wildlife. In addition, tree rings of old ponderosa pine trees are important for scientists to understand fire history, changes in climate, and other aspects of ecosystems. The following activities will provide students with a better understanding of old and large trees:

- Determining Reference Conditions
- Who Lives Here?
- Dendrochronology Detectives
- Tree ID/Size Structure

Goal 3: Enhance native plant populations and reduce invasive, non-native plant populations

Native grasses and forbs are an important part of Southwestern ecosystems. These plants make up the understory and contribute much of the biological diversity in forests. Understory plants provide food and cover for fungi, insects, birds and butterflies, mammals and other organisms. They also help protect soil from erosion and provide forage for grazing animals.

Understory plants also play an important role in carrying fires in ponderosa pine forests. When grasses are dry and abundant, they enable low-intensity fires to burn across the forest floor. Without enough understory, fires will not spread and will be unable to perform their natural functions.

Some plants are not native to an area and can take over large parts of the understory, displacing native species. Invasive, non-native plants can have negative effects on an ecosystem because they compete with native plants for space, light, water, and nutrients. They also can change the timing and role of fire in a system. The threat of fire from non-native species is particularly significant in riparian communities. In these systems, dense thickets of Russian olive and salt cedar (also called tamarisk) can lead to high intensity fires that are not natural to the system. Salt cedar, in particular, can thrive after a fire, while native species that are not adapted to fire do not fare well after such fires. Some activities that will provide students with a better understanding of understory plants include:

- Determining Reference Conditions
- Understanding Forest Fires
- Who Lives Here?
- What's Growing Up?

Goal 4: Conserve wildlife habitat and populations

There are two kinds of goals for wildlife as part of ecosystem restoration, depending on the type of project. If a project is specifically designed to restore habitat for wildlife, the goal is to create conditions that support native animals. For projects that do not specifically set out to restore wildlife habitat, the goal is to minimize negative impacts on wildlife.

Monitoring either of these goals is difficult because many animals hide from humans or are difficult to identify. To monitor wildlife it is often necessary to rely on more indirect indicators and measures. These can include "wildlife indicators" or "habitat conditions." Wildlife indicators are animal species, such as birds and butterflies, that can help show changes in an ecosystem that may affect other species.

Habitat conditions help to show if an area is good for wildlife. A habitat refers to the place where an animal is usually found and includes food, water, shelter, and nesting conditions that an animal needs to survive. Some animals rely on dense forest habitat, while others need open areas, and many need a variety of these conditions to survive. Smaller animals may use a very small area as habitat. A beetle may rely on only a small clump of plants for its habitat. In contrast, a mountain lion may have a habitat of a hundred square miles or more.

Large trees are important to many different kinds of animals, including goshawks, songbirds, wild turkeys, woodpeckers, and bats. When large trees die and remain standing, they are called snags. Snags are important to cavity-nesting birds, such as northern flickers, house wrens, and mountain bluebirds, which rely on these trees for nesting.

Two owls in the Southwest are closely associated with old-growth forests of ponderosa pine. Old-growth forests are patches of forest where old and large trees are found along with trees of other sizes and ages. Both the flammulated owl and the spotted owl tend to spend most of their time in forests with old and large trees. These owls rely on large trees as perches while searching for food. They also use large trees to nest high off the ground.

When trees are grouped in clumps, they can provide important habitat for squirrels, bear, turkey, deer, and elk. Other habitat conditions important to wildlife include understory plants for food and cover and woody trees, such as oaks and junipers, that provide large amounts of food for many animals. In addition, some dead wood on the ground provides habitat for small mammals, including those that store seeds from trees on the ground.

Some animals also need open areas for their habitat. For example, mountain and western bluebirds and spotted towhees are more common in open ponderosa pine forests than in dense forests where fires have been suppressed for many years. The bosque provides many different habitats that are important to wildlife and contains the greatest diversity of plants, birds, and animals of any Southwest ecosystem.

Some activities that will provide students with a better understanding of wildlife indicators or habitat conditions include:

- Who Lives Here?
- For the Birds
- Bosque Boogie
- What's Growing Up?

Goal 5: Conserve soil resources

Soils are the foundation of any ecosystem and are an essential part of ecosystem health. Soils can easily be damaged when they are exposed to high-intensity fires or when heavy equipment moves large amounts of soil or packs it down hard. Damaged soils can take a long time to recover. When soils are damaged, they are more likely to be invaded by non-native plants. The soil also becomes less favorable for tree seedlings to establish, and water is less likely to soak into the soil, which can lead to erosion.

Soil actually refers to much more than "bare dirt." There are many components and functions of soil. For example, many organisms live in soil, including fungi and bacteria which help to free up nutrients so that they are in a more useable form for plants. Soil also stores seeds of many plants and provides homes for many invertebrates and small mammals. The following activities will help students better understand the role of soil in an ecosystem:

- Who Lives Here?
- Compaction Action

Goal 6: Conserve and protect riparian communities

Riparian communities are shady areas of trees, shrubs, and herbaceous plants that grow along streams and rivers. They currently occupy less than one percent of the arid Southwest, but they have the greatest diversity of plants, birds and animals. Bosques provide habitat for many threatened or endangered species, yet these systems are among the most threatened in the Southwest. Threats include higher risk of destructive fires; lowered water table; impacts from overgrazing; invasion by non-native plants including salt cedar (tamarisk), Russian olive, and Siberian elm; and clearing for development. The following activities will help students better understand riparian communities.

- Determining reference conditions
- Bosque Boogie
- What's in a Watershed?
- Who Lives Here
- For the Birds
- Tree ID/Size Structure

Introduction to ACTIVITIES

This section provides activities for the classroom and field. Activities 1-6 provide background content for understanding restoration and monitoring goals. Activities 7-13 help to deepen students' understanding of monitoring and field data. A brief summary of each activity's objectives are listed below.

Students will use data analysis skills to determine reference conditions for a restoration site. Students will learn about the tools available to determine past conditions of an ecosystem and how to apply these in determining appropriate restoration goals.

Students will be able to identify the three components fire needs to burn, understand conditions that cause fire risk and spread, and describe the characteristics of crown and surface fires.

Given a physical model of a forest stand, students will learn the effects of slope, tree density, and ground fuels on fire spread.

Students will select fuels of different flammability and arrange them so they are most likely to burn. Students will describe their observations and how they relate to the restoration objectives of creating conditions that support low-intensity surface fires.

Students learn to describe how tree growth rings are formed. When given a cross-section of a tree trunk (or a photographed cross-section), students will be able to estimate the tree's age and determine how many fires have scarred the tree. Students will learn to calculate the average interval between fire scars. They will apply this knowledge in determining reference conditions for restoration.

In a recently burned area, students can find plants, animals, and animal sign, and use them to infer characteristics of the fire and fire ecosystem.

Using observation skills, students will learn that forests provide many different habitats for diverse animals.

Determining Reference Conditions

A fundamental part of ecological restoration is to understand the natural or historical conditions of the system that is being restored. Scientists need to uncover what a forest looked like or behaved like in the past, before the system was damaged or changed. Scientists often use these past conditions, called "reference conditions," as targets for restoration activities in the present.

In this activity, students will learn about different tools to determine reference conditions, and will apply these tools to specific case studies. They will gather information about past conditions of an ecosystem and will work in teams to describe reference conditions. They will apply this knowledge to a restoration site and discuss what actions might be needed to restore a site. This is a classroom activity that can also involve some library research. It can be adapted to a particular CFRP project as well.

Objectives

Students will use data gathering and analysis skills to determine reference conditions for a restoration site. Students will learn about different kinds of information that scientists can use and apply to understanding a system. They will learn about the tools available to determine past conditions of an ecosystem and how to apply these in determining appropriate restoration goals.

Relevant Monitoring Goals

change fire regimes, preserve old and large trees, enhance native plants/reduce non-native plants, conserve and protect riparian communities

Relevant Monitoring Indicators

density and size of living and dead trees, seedling density, extent of canopy closure, height from ground to base of tree crowns, amount of surface fuel, understory cover, landscape openings

Duration

50 minutes

Vocabulary

reference conditions

tree rings

ethnobotany

If you want to restore an ecosystem, how do you know what conditions it was in before it was changed, and therefore how to restore it?

Background

Researchers use a variety of tools to investigate past ecological conditions. Some are biological and some are cultural. Examples of biological evidence include tree rings and pack rat middens. Examples of cultural data include old photographs and documents such as diaries and logs of early explorers.

Sometimes people have been influencing an ecosystem for so long that physical evidence – whether biological or cultural – does not exist to show its natural state. In these cases, scientists have to apply what they know from research to estimate historical conditions for a system or site. At other times, changes in an ecosystem are recent enough that scientists can reconstruct what the system was like with a much greater degree of accuracy. Some methods that help to estimate past ecological conditions include:

- Ethnobotanical evidence, such as oral histories; anthropological literature about native peoples' uses of plants for food or medicine; and analysis of materials used to make baskets, clothing, food bags, etc.
- Written records, including the logs and diaries from explorers, military expeditions, trappers, missionaries, and merchants
- Census data, including population and land surveys
- Reports from early scientific expeditions
- Old maps and photographs
- Old aerial photographs
- Physical evidence from the ecosystem being studied, such as tree ring data, fire scars, and pack rat middens

While scientists use a combination of all these forms of information to try to determine past ecological conditions for a system, restoration is sometimes called an "imperfect science," because there are possibilities for inaccuracy in reports, exaggeration in diaries, or natural variations in a landscape that a single photograph or document cannot capture. In addition, all ecosystems naturally change with time so there is no single set of conditions that existed in the past. More likely, any ecosystem had a natural range of variation in conditions, so that, for example, some ponderosa pine forests were more densely populated with trees, while others were open areas scattered with old, large pines.

Materials:

- Photocopies of student investigator cards
- Completed packets for student investigations, including worksheets
- Accompanying CD with photographs for Dendrochronologist and Environmental Historian

Preparation

You will need to prepare materials for student investigations in advance. To do this, cut out enough "student investigator cards" (provided on page 19) so that each group of students can receive one of the four cards. These can be photocopied and cut out from the worksheet that follows this activity. You will also need to prepare student investigation packets. You will need one of each of these. If you have a large class, you may want to make two of each so that all students will be able to interpret materials. For student investigations as the Dendrochronologist and the Environmental Historian, it is best to make colored photocopies or print-outs from the CD that accompanies this curriculum and to use the student investigation text only as a reference.

If your class is particularly interested in determining reference conditions for the CFRP monitoring site, you may want to gather additional materials that students can interpret, or plan a trip to a local library or to some of New Mexico's larger archives, such as at the University of New Mexico.

Procedure

1. Introduce the topic of restoration by asking students to describe in sketches and words the CFRP project site they are monitoring. If students have not previously visited a site, ask them to sketch and describe in words a forest that they are familiar with. Have them use as much detail as they can, including names of plants and animals, existence of meadows or forests, and so on.

2. Next ask students to list all the ways they can think of that their families use the forest and its products. Examples of uses might include for picnics and hiking, for gathering fuelwood, hunting wild turkeys, collecting pinyon nuts, cutting small trees for latillas, or gathering medicinal plants for grandparents.

3. Explain that student drawings or lists of family uses are similar to what scientists sometimes draw upon to determine the conditions of ecosystems 100 or more years ago. Ask students to give the pros and cons for using this information as a reference for restoring the forest. (Pros include documentation of many of the plants and animals that existed in the forest; Cons include limited spatial references, possible mis-identification of plant species, or exaggerated perceptions of explorers as they moved from flat and open plains to a forested, mountainous region.)

4. Ask students to think about other kinds of evidence scientists might use to determine past conditions of an ecosystem. Introduce the term *reference condition*, and explain the importance of this in restoration efforts.

5. Next explain to students that they will break into groups of "investigators." Students will examine evidence from an ethnobotanist, military expedition, environmental historian, or restoration ecologist.

6. Pass out student investigation cards to each of the students. Have students arrange themselves into like groups (so that all the military expeditions, all the ethnobotanists, all the historians, and all the restoration ecologists are working together in like groups).

7. Give each group their respective packet of materials that they will use to analyze and determine reference conditions.

8. Tell students that they have 10 minutes to analyze the material they are given and to list what kinds of data they kind find from their sources. They should record data on their investigator's worksheet.

9. After 10 minutes, ask each team to present their findings to the class as a whole. On a classroom board, flip chart, or overhead projector, record these findings as students present them.

10. When each group is finished presenting their findings, ask students to look at the findings as a whole and to identify commonalities from the different sources of data.

11. Ask students to create a list of reference conditions that they feel fairly certain might have represented the site 100-150 years ago.

12. Ask students how they would apply these conditions to the forest they described earlier. What changes would need to be made to the site in order for it to look like it did 100-150 years ago?

13. Points of discussion:
    - What are some of the pros and cons in using different types of data to determine reference conditions?
    - If you are trying to restore a forest today, how would you use these types of data in deciding how to manage the forest?
    - Can any of these types of information be used in monitoring a particular site? Discuss how they might be used and any limitations of the information in monitoring.

ACTIVITY 1

Determining Reference Conditions
Student Investigator Cards

You are an ethnobotanist and document cultural uses of plants among Native Americans. You are particularly interested in materials from the 1850s to the 1950s.	You are part of a military expedition, and are impressed by the landscape of the Southwest and write about it in your diary and reports. The year is 1858.
You are a restoration ecologist and are studying tree rings to learn about forests of the past.	You are an environmental historian and analyze aerial photographs, maps and pictures to determine what the West was like at the beginning of the 20th Century.

ACTIVITY 1

Determining Reference Conditions
Student Investigations

Ethnobotanist[1]:

You are an ethnobotanist, studying the Native American uses of grasses for basket making. This is some of the information you have found:

Grasses were important to many Native American tribes for food, thatch for houses, arrows, and coiled baskets. According to interviews, at least 20 California Indian tribes use one type of bunch grass called deergrass to make baskets, which are used as bread molds, dishes for eating, acorn flour-sifting baskets, storage baskets, gifts, and grass seed collecting baskets. Many of these baskets are still woven and used today. In order to make baskets, weavers needed large amounts of deergrass. For example, to make some of the larger baskets, weavers might require as many as 3,000 or more flower stalks for a single basket.

Deergrass historically had a wide distribution in open areas, and required fire to maintain. Historic records show that many California Indians managed grasses by setting prescribed fires. This helped regenerate the grasses and eliminate grasshoppers. Though it mostly grew in open prairies, there is also evidence that two mountain tribes, the Foothill Yokuts and Western Mono, used local supplies of this grass in their baskets. One field researcher recorded that the grass also grew in the mountains at elevations of 5,000 feet in the year 1900. Deergrass commonly grew along with shrubs and small trees and in ponderosa pine forests. When shrubs or ponderosa pine trees were "encroaching" into deergrass collection sites, many tribes would burn these grasslands to maintain deergrass colonies and eliminate ponderosa pine trees. Burning could occur every 2-5 years, depending on conditions at each site.

[1]All information comes from M. Kat Anderson's article, "The Ethnobotany of Deergrass, Muhlenbergia rigens (Poaceae): Its Uses and Fire Management by California Indian Tribes." Published in Economic Botany 50(4): 409-422. 1996. Though ideally we would have provided ethnobotanic information from Southwest plants species and native uses, this information has not been published for New Mexico's native people. If students are interested in documenting local information of a similar nature, they may conduct interviews and oral histories with local people, and use this information to try to determine past conditions of an area.

ACTIVITY 1

Determining Reference Conditions
Student Investigations

Military Expedition:

You are part of a military expedition, and have recorded the following in your journal:

September 8, 1858: "We come to a glorious forest of lofty pines, through which we traveled 10 miles. The country was beautifully undulating, and although we usually associate the idea of barrenness with the pine regions, it is not so in this instance; every foot being covered with the finest grass, and beautiful broad grassy vales extending in every direction. The forest was perfectly open and unencumbered with brush wood, so that traveling was excellent."

September 21, 1858: "A vast forest of gigantic pine, intersected frequently by extensive aspen glades, sprinkled all over the mountain meadows and wide savannahs, filled with the richest grasses, were traversed by our party for many days."

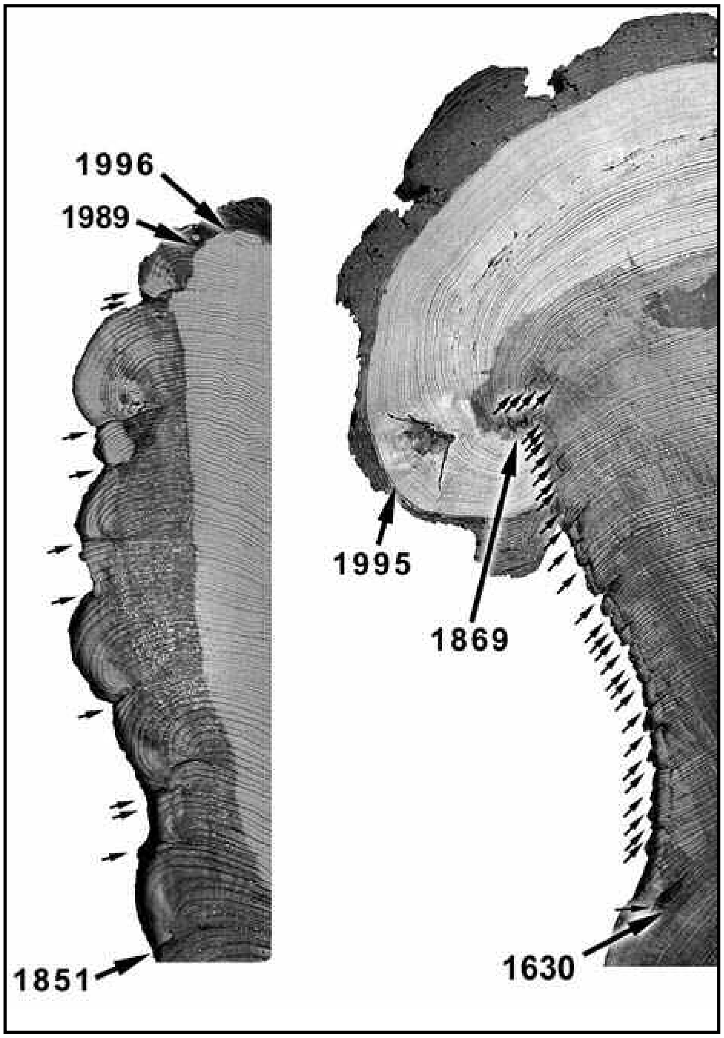
May 5, 1882: "The trees are large and noble of aspect and stand widely apart, except in the highest part of the plateau where spruces predominate. Instead of dense thickets where we are shut in by impenetrable foliage, we can look far beyond and see the tree trunks vanishing away like an infinite colonnade. The ground is unobstructed and inviting. There is a constant succession of parks and glades—dreamy avenues of grass and flowers winding between sylvan walls, or spreading out in broad open meadows...The way here is as pleasing as before, for it is beneath the pines standing at intervals varying from 50 to 100 feet, and upon a soil that is smooth, firm, and free from undergrowth."

ACTIVITY 1

Determining Reference Conditions
Student Investigations

Dendrochronologist:

You are a dendrochronologist and study tree ring scars. Analyze the attached photos as part of your research.



ACTIVITY 1

Determining Reference Conditions
Student Investigations

Environmental Historian:

You are an environmental historian and are studying the area of Walker Lake. You have two photos from 1875 and 2003 to get started with your research.

Walker Lake 1875

Walker Lake 2003

ACTIVITY 1

Determining Reference Conditions
Student Investigators Worksheet

Name ____
Date________________________

What is your job?____

What is the year(s) you have information from?________________________________

What kinds of documents did you have to analyze? ______________________________

____

What types of plants were at the site described? ______________________________

____

What kind of habitat types did you find evidence of? (For example, did you find meadows, forests, wetlands, open plains, or others?)

____

____

____

Was there any evidence of fire? If so, what was the evidence? Do you know the intervals of fire from your data?

____

____

____

What does this tell you about historic site conditions? (Do you know if the site was densely forested, relatively open, meadows, wetlands, had frequent fires, etc.)

____

____

____

Are there any other conditions at the site that you know of?

____

____

____

ACTIVITY 2

Understanding Forest Fires

A similar activity is found in Project Learning Tree, pages 311-315.

The way forests burn depends on many things: the structure of the forest, local weather conditions (whether it is dry or relatively wet), wind speed, and other factors. Because people have suppressed surface fires in ponderosa pine forests for many years, these forests are now more vulnerable to crown fires. One of the goals of many restoration projects is to minimize the likelihood of such crown fires. This can be achieved through different methods, depending on the existing structure of the forest.

In this activity, students learn the three elements of a fire triangle and the terms used to describe a forest fire. They apply this knowledge in the construction of felt board models of surface and crown fires. They interpret what they have learned in relation to restoration efforts to reduce the risk of crown fires in ponderosa pine systems.

Objectives

Students will be able to identify the three components fire needs to burn, understand conditions that cause fire risk and spread, and describe the characteristics of crown and surface fires.

Relevant Monitoring Goals

Change fire regimes, preserve old and large trees, enhance native plants/reduce non-native plants

Relevant Monitoring Indicators

Density and size of living and dead trees, seedling density, extent of canopy closure, height from ground to base of tree crowns, amount of surface fuel, understory cover, landscape openings

Duration

50 minutes

Vocabulary

ignition
fire risk
fire manager
fire severity
fire intensity
fire spread
slope
surface fire
crown fire
spot fire
drought
alpine meadow
slash

Want to learn some forest fire basics?

Materials

- Chalkboard or dry erase board with marker
- String or thick yarn approximately 10 feet in length
- Construction paper or notecards
- Felt board - cardboard, felt in different colors, scissors
- Copies of worksheet

Preparation

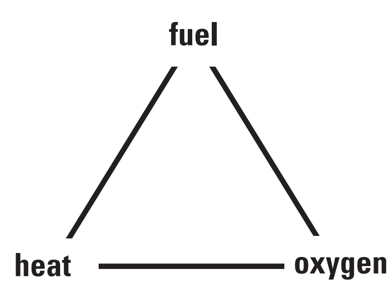
You will need to prepare materials for the fire risk and felt board activities in advance. At the end of this activity, there are sample scenarios that can be photocopied and cut for the fire risk activity. Or you may wish to use some of these scenarios and create others more appropriate to your field site. For the felt board, you will need a piece of corrugated cardboard or other hard backdrop. Cover this with the background: use a big sheet of blue felt for a sky, use brown felt for the ground. It is good to create some amount of hills or slopes for higher grades. Sample patterns are provided at the end of this activity that can be copied and traced onto felt of different colors. Or, if you are planning to use the Tree ID activity, you could have students create felt cut-outs as an extension of that activity. Students really enjoy placing the lightning bolt onto the felt board, so make sure to cut one of these out, too.

Procedure

1. Introduce the lesson by asking what students think about forest fires. Ask students to say if they think fires are "good," "bad," or "sometimes good and sometimes bad." Have them explain their thinking for each of these categories.

2. Ask students for feedback about how fires start (Look for natural fires - through lightning; human-caused - campfires, cigarette butts, burning debris, sparks from ATVs or other vehicles, etc.). Explain that these are sources of ignition and are needed to provide heat to start a fire.

3. Ask students what three things a fire needs to burn: have them generate a list of as many things they can think of and categorize them according to the three elements of the fire triangle:



4. Have students think about a "perfect day" for a forest fire using the triangle:
   - Oxygen (windy days - fire season in spring, direction of wind, hills)
   - Heat (when is fire season, do fires usually burn most in the day or night)
   - Fuels (wet versus dry, size of fuels)

   Ask students to think about what a fire manager (someone who manages fires on public lands) can control? Can they control oxygen? (no). Can they control heat? (no). Can they control fuels (yes). Explain that for this reason, many restoration projects focus on fuels in order to change fire behavior so it is less risky.

5. To apply this knowledge, have student play a game. Each student will take a piece of paper from a bag and decide if the scenario on their paper is a low, moderate, or high fire risk. To play the game:
   - Place a yellow card marked LOW and a red card marked HIGH at either end of a 10-foot long string.
   - Have each student pick one paper with a scenario from a bag.
   - Have each student decide the fire risk (standing by the low end or high end or in the middle) for their scenario
   - Have students read their scenarios to the class and explain why they chose the level of fire risk. (You can make scenarios increasingly complicated depending on the age of the students.)

6. Next introduce how fires are described:
   - Fire intensity (how hot it burns)
   - Fire severity (how much it kills)
   - Rate of spread

   Discuss what factors might affect fire intensity, fire severity, and rate of spread, using the fire triangle to discuss each of these factors.

7. Bring out the felt board and explain to students that they are going to use the felt board to model different kinds of fires. Discuss how the felt pieces represent different aspects of the forest, and have students identify what each color and shape of felt represents (for example, ponderosa pine trees, oak shrubs, grasses, and fire).

8. Ask the class who has heard of a surface fire. If someone has heard of it, ask them to explain what they think it means. Next ask who has heard of a crown fire, and ask them to explain what it means.

9. Have 2 students volunteer to use the felt pieces to create conditions that would support a surface fire.

10. Have 1 student volunteer to place the lightning bolt on the felt board to start the fire.

11. Have another student volunteer to show how the fire might spread. Have the class evaluate the fire spread as the student places fire pieces onto the felt board. Have the class decide whether the felt board model would indeed remain a surface fire, or if they think it might become a crown fire. Look for presence of ladder fuels, many connecting tree canopies, or dense fuels on slopes. Also look for enough ground fuels (such as grasses and shrubs) to carry a fire across the surface. Have students use the words fire intensity, fire severity, and rate of spread to describe the fire modeled. If appropriate, have 2 more students adjust the felt board so that it would support a surface fire.

12. Discuss how a surface fire might be beneficial to the forest. (Nutrient cycling/provide nutrients for plants, killing small trees that would create an over-crowded forest, reducing fuels, reducing fire risk to nearby homes, provide new areas for grass growth, lower fire severity and fire intensity less damaging to old and large trees, fire spreads quickly and is less damaging to soils).

13. Next, have 2 students volunteer to use the felt pieces to create conditions that would support a crown fire.

14. Have 1 student volunteer to place the lightning bolt on the felt board to start the fire.

15. Have another student volunteer to show how the fire might spread. Have the class evaluate the fire spread as the student places fire pieces onto the felt board.

16. Have the class evaluate whether the felt board model would likely lead to a crown fire. Look for presence of ladder fuels, tightly grouped tree crowns, or dense fuels on slopes. Have students use the words fire intensity, fire severity, and rate of spread to describe the fire modeled. If appropriate, have 2 more students adjust the felt board so that it would support a crown fire.

17. Discuss the effects a crown fire might have on the forest. (Can kill large and old trees, can be high fire intensity (so damages soils), can be high fire severity (so can be catastrophic - burning everything), can trap wildlife and kill them, can create openings (creating meadows).

18. Ask class what people think about forest fires again. Compare answers to beginning of class.

19. Evaluation: Have students complete the accompanying worksheet, and/or have them re-create drawings that model surface and crown fires and write accompanying explanations.

ACTIVITY 2

Understanding Forest Fires
Forest Fire Worksheet

Name____

1. Fires need three different things to burn. Draw a triangle below and label each of the three sides with a word and picture for each part of a fire.

2. What part of the "fire triangle" you just drew in question 1 can be changed by humans to reduce the risk of fire?

3. Heat for a fire comes from an "ignition source," which can be human or natural. Name three different sources of heat that can start a fire:

   1. ____
   2. ____
   3. ____

4. Fires need fuel to burn. Name three types of fuel you might find in a forest:

   1. ____
   2. ____
   3. ____

5. Name two possible effects of a surface fire on the forest:

   1. ____
   2. ____

6. Name two possible effects of a crown fire on the forest:

   1. ____
   2. ____

Activity 2. Understanding Forest Fires; Answer Key to Worksheet: 1. Heat, fuel, oxygen are the three parts of the triangle; 2. Fuel can be reduced by fire managers through thinning and controlled burning; 3. Possible answers: lightning, campfire, cigarettes, matches, sparks from cars or off-road vehicles; 4. Possible answers: pine needles, fallen trees, dry shrubs, live trees, grasses, branches and tree limbs; 5. Possible answers: reduce fuels, reduce fire risk, provide nutrients for plants, provide new areas for grass growth, can kill small trees or shrubs; 6. Possible answers: can kill large and old trees, burns hot (so damages soils), can be catastrophic (burning everything), provides large openings (creating meadows)

ACTIVITY 2

Understanding Forest Fire
Scenarios for Understanding Fire Risk

It hasn't rained for 3 months.

It hasn't rained for 3 months, and it is a very windy day.

It is a cloudy winter day, and snow is expected for the next 3 days.

It is a hot, dry summer, and a lightning storm comes at night.

It is a dry winter and a dry spring. Someone forgets to put their campfire all the way out.

There is no rain for many months. Many trees die. The dry needles are still on the trees.

Someone cuts many small trees and leaves them on the ground in large piles in the forest.

It is a hot summer day, and there has been no rain for 2 months.

It is a cool spring morning after a light rain.

It rained for 4 days, setting a record for the most rainfall in one week

A lightning storm hits in a wet, alpine meadow.

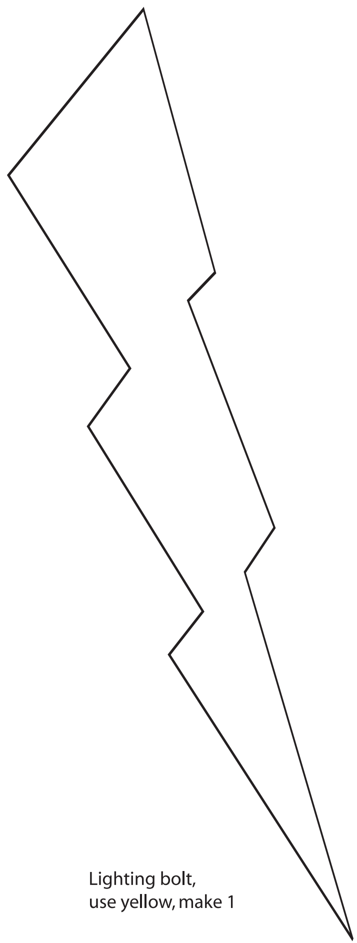
It is a dry winter and a dry spring. Someone throws a cigarette butt in the forest.

There is a drought, and many trees die. The dry needles fall from the trees onto the ground.

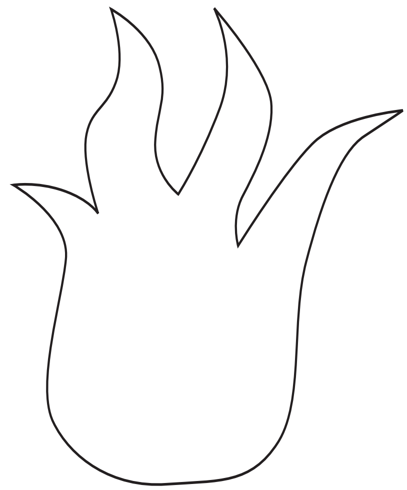
Someone cuts many small trees. They remove the trees and spread the slash over the ground.

ACTIVITY 2

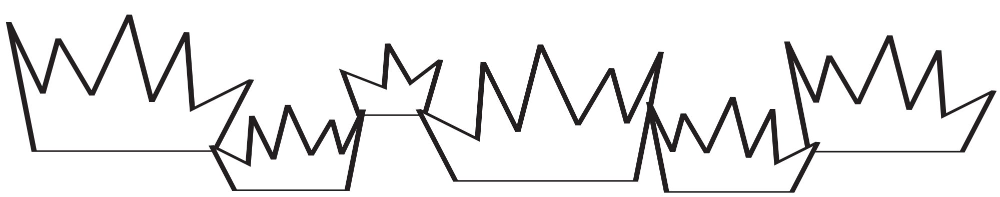
Understanding Forest Fires
Felt Board Patterns



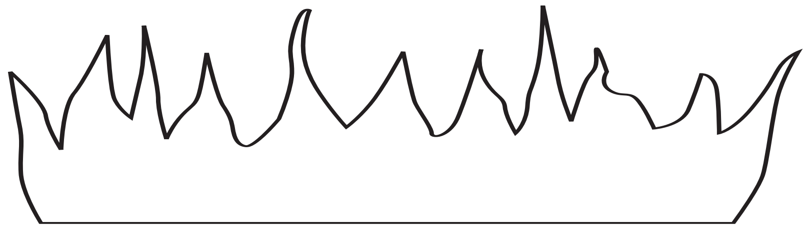
Lighting bolt,
use yellow, make 1



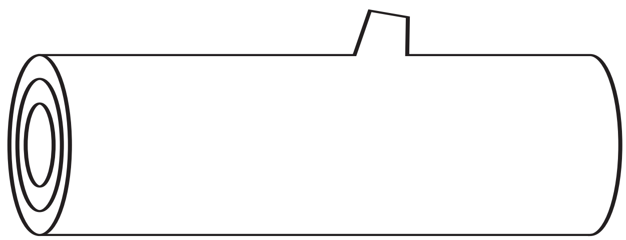
Spot or crown fire, use red, make 5



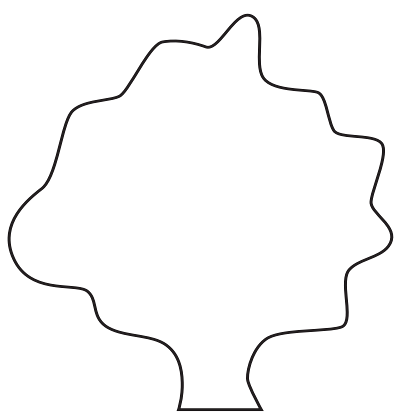
Grasses and forbs, use sage green, make 3



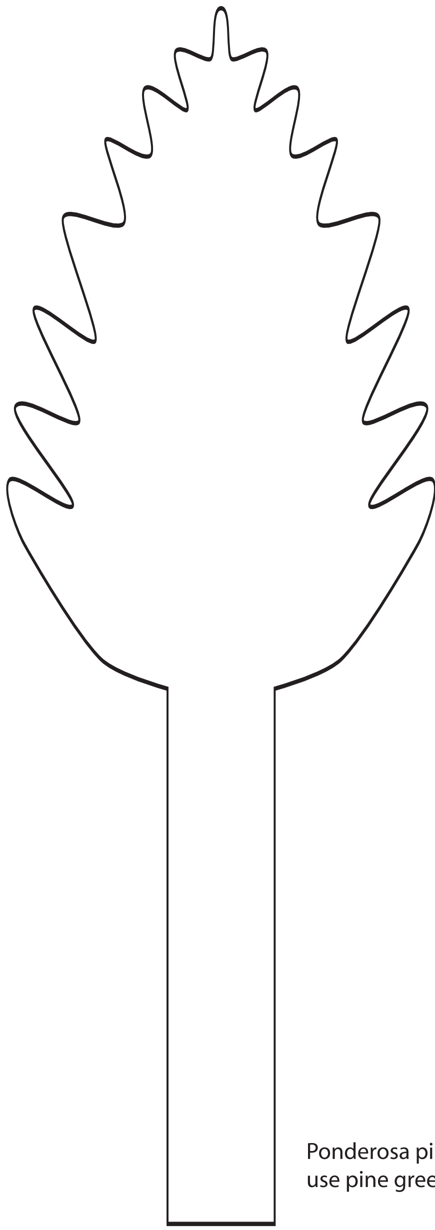
Ground or surface fire, use red, make 4-5



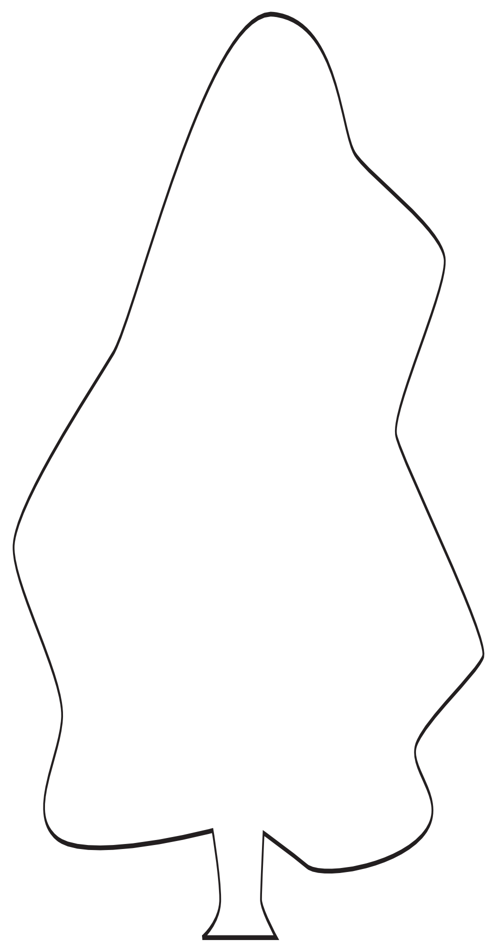
Small log or branch, use dark brown, make 5-10



Single scrub oak, use gold, make 4



Ponderosa pine,
use pine green, make 6



Pinyon-juniper (bushy form),
use pine green, make 8

ACTIVITY 3

Modeling the Fire Triangle in Wildlands

Adapted from FireWorks Activity 3-4, pages 43-46.

Sometimes restoration projects seek to return more natural fire intensities and intervals to forests. Surface fires were a natural component of many western forests in the past. In order to recreate conditions that will support surface fires, some restoration projects remove trees from the forest. This "thinning" of the forest to different densities of trees helps create patterns of burning that maximize the number of trees that remain standing in the forest after a fire.

In this activity, students will use models to understand fire behavior under different variables. They use matches to model trees and a matrix of matches to model a forest. They compare fire behavior on different slopes and with different arrangements of trees. They interpret what they have learned in relation to monitoring indicators for changing fire regimes.

NOTE

This activity involves fire. You will want to work in a very safe laboratory setting or outdoors. If working outdoors, select a location that is far from any vegetation, wood chips, cars, buildings, or other fuels. (An empty parking lot can work well.) Make sure plenty of water is available to put a fire out. You may need to have teachers' aides, a CFRP project partner, or volunteers assist with this activity.

Objectives

Given a physical model of a forest stand, students can describe effects of slope, tree density, and ground fuels on fire spread. Students can describe these effects using the terms surface, crown, and ground fire.

Relevant Monitoring Goals

change fire regimes

Relevant Monitoring Indicators

density and size of living and dead trees, seedling density, extent of canopy closure, landscape openings

Duration

50 minutes

Vocabulary

crown fire

tree density

ecologist

forester

model

slope

surface fire

Are your students interested in fire behavior?

Materials

- 4 matchstick forest kits (1/4" thick masonite with drilled holes evenly spaced across; box of strike-anywhere large kitchen matches)
- 1 long bolt, 1 short bolt with nuts and washers
- 4 nails
- 4 burning trays (tin pie pans work well for this)
- fire extinguisher

Procedure

1. Set up the class with four student teams. Explain that this activity is similar to research done by chemists and physicists. Results from research like this are used by foresters, firefighters, and ecologists.

2. Explain that each team will set up different experiments, but the whole class will observe every fire. So, in effect, the student teams are setting up demonstrations for the whole class.

3. Review safety procedures in the laboratory.

4. Give each student team a matchstick forest model set with 50-100 matches. Ask students to insert a match in every hole of the forest model, tips pointing UP.

5. Set these "matchstick forests" in burning trays on a heat-resistant surface. If you don't have laboratory facilities, one really good surface to use is a trash-can lid filled with sand.

6. Assign a demonstration to each of the four student teams:
   1) a level forest;
   2) a forest with a 20-degree slope (use the nut and short bolt to create the slope);
   3) a forest with a 40-degree slope (use the nut and long bolt). Have a fire extinguisher and water nearby.

7. Explain to students that the individual matches represent trees that have flammable crowns like the ponderosa pine trees. In this demonstration, students will observe how slope and tree density affect fire spread through tree crowns. Before lighting any matches, ask students for their hypothesis (guess) about how the fires will differ.

8. Have a student light a fire for each of the demonstrations:
   1) light the flat "forest" along one edge and observe;
   2) light the TOP row of matches of the 20-degree slope forest;
   3) light the BOTTOM row of the second 20-degree forest;
   4) light the bottom row of the 40-degree forest. After each demonstration, ask the students what they observe and what this means in terms of the fire triangle and forest restoration. Have the students answer the following questions:

      A. How does the steepness of a hillside affect a fire's spread?
      B. How well do fires burn downhill?
      C. How does slope affect fire spread? Use the fire triangle to explain (Heat travels upward, so the matches and trees uphill from a fire receive more heat than those below and are easier to ignite.)

9. Ask students to remove whatever remains of the matches from each board. They can use the nails to poke burned matches out if necessary.

10. Explain that the arrangement of "trees" in the matchstick forest demonstrations just completed resemble very dense forests. Ask students to arrange the forests so that they resemble possible prescriptions for ponderosa pine according to the following demonstrations: 1) creating defensible space at the edge of a community with moderate (20-degree) slopes; 2) creating a mosaic of tree clumps and open areas with 15-20 trees total on flat ground; 3) creating a forest of 35 trees on a steep (40-degree) slope to reduce the risk of fire spread; 4) creating a forest of 25 trees on moderate (20-degree) slope to reduce the risk of fire spread. Or ask students to alter their forest models so that they change one variable at a time to determine effects of slope, wind, or tree density on fire behavior.

11. Have students light each of these matchstick forest demonstrations and observe what happens. Discuss how well each team solved the problem they were given and what could have been done differently.

12. Ask students to compare the model forests in this experiment to real forests. What is similar? What is different?

13. Applications to monitoring sites:

    - Have students discuss what conditions are present in the site they are monitoring, and what might happen in this forest if there was a fire.
    - Have students look on a project site map and find areas that they think would be susceptible to a crown fire.
    - The next time students are collecting monitoring data in the field, have them identify areas in the forest that they think might be susceptible to a crown fire.
    - This activity could be done when collecting baseline data and then repeated after the forest is thinned. Students could then compare areas at risk of crown fire before and after the project is treated.

Bucket Brigade

Adapted from FireWorks Activity 3-5, pages 49-52

All forests contain woody fuels, such as dead and down logs, beds of pine needles, low branches of live trees, and dense thickets of small trees. Although these fuels are a natural part of any forest, high levels of such fuels can carry a fire from the ground into the tops of trees, leading to a crown fire. Forests where fire has been suppressed for many years might contain high levels of these fuels. Restored forests should contain low levels of these fuels. When large amounts of woody fuels exist, they must be removed from the forest before a surface fire can be safely reintroduced to a forest.

In this activity, students will experiment with the flammability of different fuel recipes in a laboratory or safe outdoor setting. They interpret what they have learned in relation to monitoring indicators for changing fire regimes.

NOTE
This activity involves fire. You will want to work in a very safe laboratory setting or outdoors. If working outdoors, select a location that is far from any vegetation, wood chips, cars, buildings, or other fuels. (An empty parking lot can work well.) Make sure plenty of water is available to put a fire out. You may need to have teachers' aides, a CFRP project partner, or volunteers assist with this activity.

Objectives

Students will select fuels of different flammability and arrange them so they are most likely to burn. Students will describe their observations and how they relate to the restoration objectives of creating conditions that support low-intensity surface fires.

Relevant Monitoring Goals

change fire regimes

Relevant Monitoring Indicators

amount of surface fuel

Duration
50 minutes

Vocabulary
charred fuels
flammability
fuel
fuel moisture
surface area
volatile
volume
ignite

Can you predict how fuels will burn?

Materials

- Fuels: green pine needles attached to twigs, dry pine needles attached to twigs, small dead and dry branches (0.25-1 inch in diameter) from ponderosa pine, large dead and dry branches (1-3 inches in diameter) from ponderosa pine, charred fuels from campfire or wood stove
- 5 Burning trays (aluminum pie pans work well for this)
- Wooden matches
- Metal trash can without plastic liner
- Fire extinguisher and spray bottles with water
- 5 small buckets of water
- Recipe cards

Preparation

Collect all fuels listed above and place into grocery bags according to the recipes described below. Green needles may be stored in a plastic bag in the refrigerator for up to 2 weeks prior to the lesson. Prepare a recipe card for each of the five recipes below.

Recipe #1

GREEN pine needles attached to twigs

Recipe #2

Small dead & dry branches (0.25-1 inch) from ponderosa pine tree + GREEN pine needles

Recipe #3

Small dead & dry branches (0.25-1 inch) from ponderosa pine tree + DRY pine needles

Recipe #4

Large dead & dry branches (1-3 inches) from ponderosa pine tree + Small dead & dry branches (0.25-1 inch) from ponderosa pine tree

Recipe #5

Charred fuels from campfire or wood stove + Small dead & dry branches (0.25-1 inch) from ponderosa pine tree

Procedure

1. Review the Fire Triangle with students (from Activity 2): Discuss what three things are necessary for a fire to burn and draw the fire triangle on the board.

2. Explain that five teams of students will be trying to start small fires in the aluminum pie tins with a certain fuel mixture. They must come up with a strategy to get as much of their fuel as possible to burn within 15 minutes. (You may want to reduce this time if using a small amount of fuel for each experiment.)

3. Divide the students into five teams. Give each team a fuel recipe, the fuels they need for this recipe, an aluminum pie pan, a small bucket of water, and 7 matches. (Seven is all they get.) You could also have the students review each of the recipes and create hypotheses for how well they think each of the fuels will burn.

4. Review safety procedures and rules for this activity. These rules should include:
   a. Each team must work together
   b. The whole team is responsible for safety. If any student is injured, the experiment stops.
   c. All fires must be built within the pie tin on the designated surface (laboratory fire-resistant tables; pavement or gravel away from cars, buildings, or vegetation).
   d. Each team must stick to its recipe. No other fuels may be added.
   e. Each team gets only 7 matches. No more may be used.
   f. Each team MUST use a 2-minute group planning session before lighting any matches. They can arrange the fuels in the pie tin any way they wish. This should be agreed upon before any matches are lit.

5. Go outside or into a very safe laboratory setting where students will burn the fuels.

6. Have the students create a plan (during the 2+ minute planning session) for how they will arrange their fuels.

7. After 2 minutes, tell students they may begin lighting their fires.

8. After 15 minutes, stop the activity.

9. As a class, take a “tour” of each fuel site. Discuss how successful each fire was and why it did or did not burn well.

10. Discussion Points:

   - Green fuels have more moisture than dry fuels unless it has recently rained. Moisture affects the Fire Triangle in two ways: 1) the moisture has to evaporate before you can heat the fuel to an ignition point (about 600 degrees Fahrenheit). If fuels are really wet, the water also keeps oxygen from getting to the fuel.
   - Green fuels usually contain a high percentage of water by weight. So green fuels may be difficult to light. Dry fuels can contain as low as 3% water by weight.
   - When green fuels burn, they may produce more heat than a dry fuel. This is because green fuels contain oils and other "volatile" compounds that break down once the material is dead (and therefore are not present in dry/dead fuels).
   - Large branches are harder to light than smaller ones. Small branches and needles have more surface area that is exposed to oxygen and to the heat of the match than larger pieces. This is called "surface-area-to-volume ratio." As this number increases, fires burn more readily.
   - Plants are a mixture of flammable materials (carbon compounds that combine readily with oxygen in the presence of heat) and inflammable materials (such as silicon). Charred wood has had much of its carbon burned off, especially from the surface of the fuel, so it is harder to light.
   - Ask the students what factors other than fuel influenced how well their fuels burned. What strategies did they use to get the fires to burn?

11. Applications to monitoring:

   - Ask students to think about the site they are monitoring and discuss the fuels present. (Or discuss this the next time students go to the field site.)
   - Talk about the prescription called for in the site they are monitoring, and how this will affect the amount of fuels on the ground.
   - Discuss the types of fuels and their relative flammability.
   - Discuss whether these conditions would support a continuous, low-intensity ground fire.
   - If monitoring surface fuels, discuss any data gathered and how this relates to the goal of creating conditions to support a continuous, low-intensity ground fire.

ACTIVITY 5

Dendrochronology Detectives

Adapted from FireWorks Activity 5-1, 5-2, and 5-3, pages 91-107
Activities for Younger Grades are found in FireWorks Activity 5-1.

Tree rings provide important background information for forest restoration. Tree rings can help determine the age of a tree or a group of trees. When scientists know the age of groups of trees in the forest, they can determine what forests looked like in the past. When scientists can determine what a forest looked like 100 or 200 years ago in a particular location, they can set goals for restoring this same area today.

Fire scars on tree rings can show whether a tree has survived a fire, or many fires, when and how often these fires occurred. From this information, scientists can set goals for restoring fire to forests.

In this activity, students learn about growth rings and how fire scars form on trees. They use dendrochronology to describe the history of ponderosa pine forests over the past several hundred years. They learn that restoration requires understanding what historical forests were like, and they learn how tree rings and fire scars can help to determine these historic conditions.

Objectives

Students learn to describe how tree growth rings are formed. When given a cross-section of a tree trunk (or a photographed cross-section), students can estimate the tree's age and determine how many fires have scarred the tree. Students will be able to calculate the average interval between fire scars. They will apply this knowledge in determining reference conditions for restoration.

Relevant Monitoring Goals

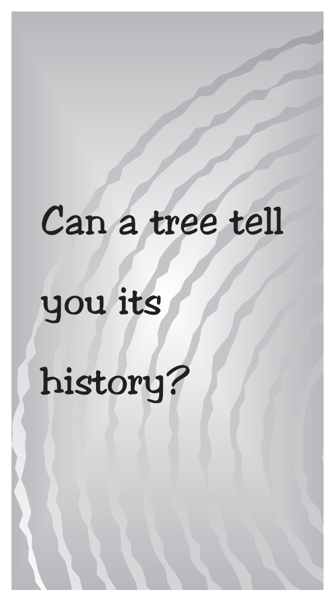
change fire regimes, preserve old and large trees

Relevant Monitoring Indicators

density and size of living and dead trees

Duration
50 minutes

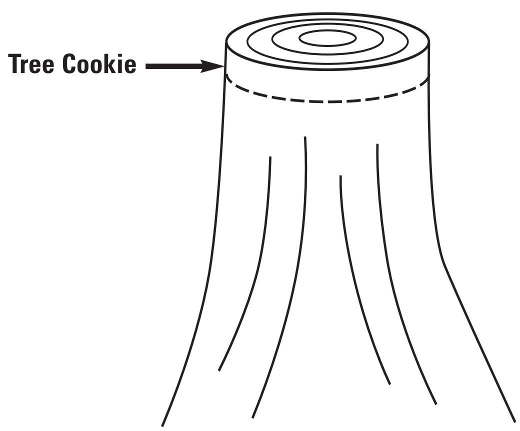
Vocabulary
reference conditions
restoration
cambium
dendrochronology
fire scar
growth ring
heartwood
sapwood
surface fire
crown fire
tree cookies
xylem
natural range of variation



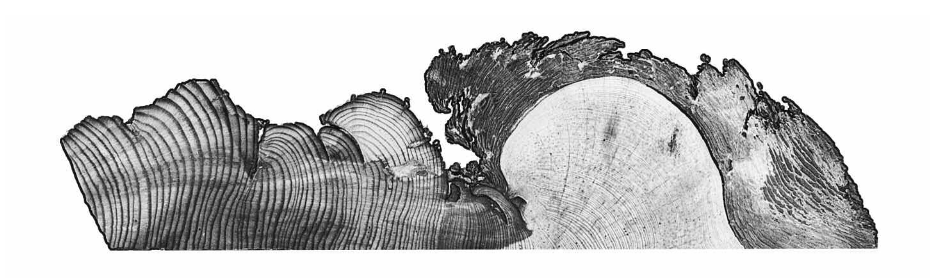
Background

Dendrochronology is the study of tree rings to determine approximate dates of past climatic and other environmental events. The study of tree rings can help scientists understand historic conditions of a forest. Scientists sometimes study tree rings by examining tree cookies, or the cross-section of trees, which are usually cut from dead trees and stumps. The tree rings on these cookies can give information about climate, such as periods of drought (represented by more narrow tree rings) or periods of higher rainfall (represented by wider tree rings). Fire scars can give clues as to the frequency and types of fires that may have been present in different types of forests in the past.

Fire scars are made on trees by surface fires that are not severe enough to kill the tree. A fire scar is formed when part of a tree's cambium is killed by the heat of a fire. If the cambium is damaged only part-way around the tree, the tree often survives. In the years after a fire, new wood forms at the edge of the damaged area. Year after year, new rings are formed that gradually curl over the edges of the damaged area. This new growth begins to cover up the fire scar. Fire scar samples usually show fire scars on one side of the sample, where the fire scorched through the bark and burned the cambium.



Historians recognize two important sources of fire prior to European American settlement of North America. Most fires were started by natural lightning, but some also were started by Native Americans. It is clear that crown fires were rare in ponderosa pine forests. The Ancient Tree picture for this activity (page 99) shows a ponderosa pine tree that survived many fires and lived for nearly 600 years. It is unlikely that there was a crown fire in the location of this tree for these six centuries.



Sample photo of a ponderosa pine tree cross-section, showing fire scars (at intervals at right edge). These are available from the FireWorks CD and a subset are available on the CFRP Monitoring Curriculum CD.

Materials

- Tree cookies from ponderosa pine (about 1 per 2-3 students)
- Tree cookie photos (if no real tree cookies are available) (about 1 per 2-3 students)
- Hand lens (1 per 2-3 students)
- Straight pins
- Ancient tree cookie photo
- Calculators
- Copies of Dendrochronology detectives worksheet

Preparation

These activities are most easily done with real cross-sections of trees (also called tree cookies). These may be available from the Forest Service or from the Laboratory of Tree Ring Research at the University of Arizona. If it is possible, try to obtain tree cookies from trees with a known history and location. You will need trees or portions of trees that contain fire scars to complete this activity. If no tree cookies are available with fire scars, you can use color copies of photographed cross-sections, which are available on Fireworks CD (see Appendix 2), or by downloading this curriculum's supplementary materials from the website: www.fs.fed.us/r3/spf/crfp/monitoring or requesting a CFRP Monitoring Curriculum CD. This activity works well if students work in pairs or groups of 3 people (at most), so you will need the appropriate number of photographs for your class size.

Procedure

1. Introduce the topic to students by explaining to them that they will be dendrochronologists for the day. Ask students to break down the word dendrochronology to see if they can figure out its meaning. (Dendro = tree; chrono = events in a time series; logy = the study of). Explain to students that the study of tree rings can help scientists understand historic conditions in the forest. Tree rings can give information about climate, such as periods of drought or periods of higher rainfall. Tree cookies with fire scars can give clues as to the frequency and types of fires that may have been present in different types of forests in the past.

2. Have students examine the growth rings on the Ancient Tree picture. The tree in the Ancient Tree photo was nearly 600 years old when it died. Look at the scars that form little notches along the blackened edge of the Ancient Tree. The scars on this tree were made by surface fires. Because this tree lived for nearly 600 years, and was only burned by surface fires in that time, we can determine that no crown fires occurred where the tree was located for nearly 6 centuries, between the early 1300s and 1919.

3. Explain fire scars to the students: Fire scars are made on trees by surface fires that are not severe enough to kill the tree. A fire scar is formed when part of a tree's cambium is killed by the heat of a fire. If the cambium is damaged only part-way around the tree, the tree often survives. In the years after a fire, new wood forms at the edge of the damaged area. Year after year, new rings are formed that gradually curl over the edges of the damaged area. This new growth begins to cover up the fire scar.

4. Explain that students are going to describe the fire history of a tree. Break students into pairs or groups of 3. If available, pass a fire-scarred ponderosa pine cookie to each group of students. (Use photos if no cookies are available.) Pass out hand lenses to students. Warning: If students are working with hand lenses in direct sunlight or near sunny windows, be alert for students trying to light fires with the hand lenses. Also distribute straight pins, Dendrochronology Detectives worksheets, and calculators.

5. Explain that students are going to be counting the rings of trees to determine the age of the tree (if the pith in the middle of the tree is present), and the number of years between each fire. Tell students they may keep track of tree ring counts by sticking pins into the wood (or photo) or by using a light pencil. They may not use ink in any form. Note: When students are counting tree rings, sometimes they will be unable to see a section clearly or to tell if there are one or two rings in a particular area. Explain to the students that when they can't count clearly, that they just estimate one ring. Then when they record the number, they should use the greater-than (>) sign, to denote that there are probably more rings on the cookie. Explain to students that this is a conservative estimate of the age or intervals between years.

6. Have students complete the Dendrochronology Detectives worksheet using their tree cookie or photo. Give students 15-30 minutes to study their tree cookies and complete their worksheets. If needed, remind students how to calculate averages. To calculate the average interval between fires, students will add up the numbers of years between each fire scar and divide by the total number of fires.

7. When students have completed their worksheets, have each student share their data. Ask them to determine an average interval of fire for ponderosa pine forests based on the entire class's data.

8. Discussion questions:
   - What does the tree ring data tell us about fire intervals in ponderosa pine forests?
   - Can we learn anything from fire scars about crown fire? Were there any crown fires in the area of each student's tree? How do they know? [The answer should be that a crown fire was very unlikely because a crown fire would have killed the tree. They know this because the tree survived its fires.]

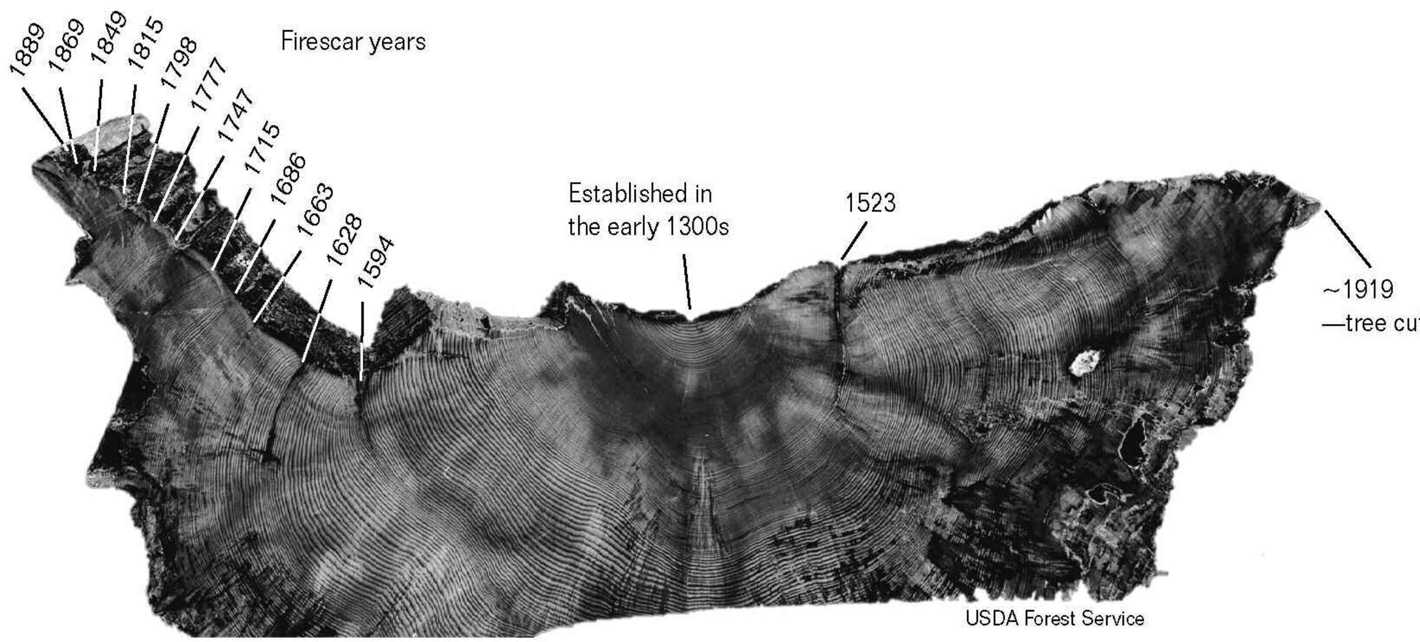
- Did the students find a particular time period (if they were able to age the tree) when fires become less frequent? Why might fires have been less frequent? [Fire suppression was extensive in the 1920s and 1930s. This was from actively putting out fires, and also from an increase in grazing, which led to a decrease in fine vegetation (fuels) to carry a fire.
- Why might some students have found poor growth after a fire, while other students found good growth? [Poor growth is likely to occur after a fire if the fire killed many of the tree's needles, or if the fire scorched much of the cambium. Rapid growth after fire may be caused by decreased competition from other vegetation for moisture and nutrients, or by an increase in soil nutrients from burned vegetation.]
- How might tree ring data be used for restoration of a particular forest? [Restoration requires the understanding of reference conditions that give information about what a forest used to look like and how it used to function. Historic fire intervals give information about how the forest used to function. Fire intervals from tree cookies can help to estimate how often a surface fire burned in the area where the tree grew. This information can be used to re-establish conditions in forests today so that surface fires may safely burn at similar intervals.]

Possible Extensions

Extension 1.

Students often ask why some of the wood in a tree cookie is dark, while other parts of the cookie are lighter. The dark wood usually marks areas that are filled with sap, or "pitch." Wood containing this pitch can develop for many reasons, including:

1. The outer wood (xylem or sapwood) is often lighter in color than the inner wood (heartwood). Xylem transports water and minerals in all plants, including trees. Xylem does not transport sap, which would give it the darker color. As trees age, cells in the inner sapwood die and become heartwood. The tree can fill the spaces in the heartwood with sap, giving it the darker color. Though the heartwood cells are not living, they provide support to the tree throughout the tree's lifespan.



Fire played a large role in the northern Rocky Mountain forests. This ponderosa pine cross-section, cut from an old stump just five miles north of Missoula, Montana, shows numerous firescars.

Have students compare the two cross-sections of trees and identify the locations of xylem, sapwood, and heartwood.

2. If a tree is wounded, it often deposits pitch around the wound. The pitch prevents fungi, which lead to decay of the wounded area, from spreading too far into the tree. The wounds are caused by many things, including scrapes from other trees, rubbing by animals, bark beetles, and fire. The pitch forms irregular, dark shapes around the wounds. Have students look at their tree cookies (or photos) for evidence of these wounds. (Fire scars are one example.)

Extension 2.
Since tree rings are windows into the past, have students compare the following dates in history with the growth rings on their tree cookies. (This extension works only if students can age the trees and the trees are sufficiently old.)

1) railroads built, 1875
2) mining boom, 1880s
3) increase in grazing, 1880s to 1890s
4) increase in fire suppression, 1920s and 1930s

Have students mark each of these dates with a straight pin and paper. Also have them note if the tree growth changed before or after these dates in any noticeable way. Ask students to explain the relationship between these events and the effects in the forest in terms of a) fire history; b) timber usage; and c) ability of ponderosa pine seedlings to regenerate.

ACTIVITY 5

Dendrochronology Detectives Worksheet

Name ____

A. Does your tree cookie have pith (a ring in the middle) or is it missing? ________
(If the pith is missing, then skip to step D.)

B. If the pith is present, estimate the age of the tree by counting the lines starting from the pith and going to the bark. How old is the tree? ________ years

C. If the pith is present, how old was your tree before it was first scarred by fire? _______

D. How many fires have burned your tree? _______

E. How many years were there between each fire? _______ _______ _______

_______ _______ _______ _______ _______ _______ _______ _______

F. What is the average interval between fires? _______

G. How long has it been since your tree's last fire scar? _______

H. Is this interval very different from the average in question F? _______ If it is different, try to explain why this might be.

I. At what age did your tree grow best? (Where are the rings the widest)? _______
(Wide tree rings show good years for tree growth, when moisture, sunlight, and nutrients were plentiful.)

J. At what age did your tree grow most slowly? (Where are the rings the narrowest?) _______
Rings that are very close together show years of drought, disease, injury, shading, or crowding by other trees.

K. Were the years right after fire usually good or poor for growth? _______

L. How do you explain your tree's response to fire (your answer in part K)?

Burned Area Scavenger Hunt

Adapted from FireWorks, Activity 9-1

Surface fires have been suppressed from ponderosa pine forests for many years. When cool surface fires are returned to a restored forest, they may have effects that in the short term seem harmful but in the long run have positive effects for the health of the forest. For example, young trees may be killed or grasses and flowers may burn to the ground.

In some cases, fire burns through a forest that has not been restored. When this happens, the forest may burn so severely that few trees remain standing. These forests may take many years to recover. Early signs of recovery may include fire-adapted plants that cover the bare ground, re-sprouting of trees from stumps, or birds that find food and/or nest in dead, standing trees.

This is an activity specifically designed for projects that plan to reintroduce fire to their restoration site or that may be restoring an area previously burned by wildfire. The activity requires a site burned by prescribed fire or wildfire. If the CFRP project site has not been burned yet, it may be still be worthwhile to conduct this activity at a nearby burned area.

Objectives

In a recently burned area, students can find plants, animals, and animal sign, and use them to infer characteristics of the fire and fire ecosystem.

Relevant Monitoring Goals

change fire regimes, preserve old and large trees, enhance native plants/reduce non-native plants

Relevant Monitoring Indicators

density and size of living and dead trees, seedling density, extent of canopy closure, height from ground to base of tree crowns, amount of surface fuel, understory cover, landscape openings

Materials

- Paper and pencil
- Photocopies of worksheet
- Clipboards or hard writing surface
- Optional: field guides for trees, shrubs, birds, mammals, scat

Duration

50 minutes

Vocabulary

field site

habitat

snag

cavity-nesting birds

old-growth forest

understory plants

Want to investigate a recent fire?

Procedure

1. Introduce the lesson by telling students they will be going into the field to observe effects of a recent fire. Give a bit of history on the fire. If possible, have a professional fire manager, forester, ecologist, and/or project partner present for this trip to share information and background on the project site.

2. Review safety guidelines, such as working in pairs, always being within eyesight of an adult, etc. Also review guidelines for working in the forest, such as using quiet voices, leaving all objects where they are found, returning rocks and logs to their original location, treating all objects in the forest with respect, observing but not disturbing wildlife, etc.

3. Depending on time limitations and group dynamics, this activity can work well with two variations:

- Variation 1: Break students into 2-person teams. Assign 2 items from the scavenger hunt to each team. Give them approximately 10 minutes to find their items. Then have each team present their items to the class as a whole and explain what they've learned. This works particularly well with groups that are independent and interested in exploration.

- Variation 2: Break students into 2-person teams. Give each team the entire scavenger hunt and have the team identify each item. Then have each team present 2 items that they think are unique or interesting to the entire class.

4. Discussion Points:

    - Ask the students to evaluate the burned area: did many trees die? Was there much regrowth of understory plants? Are there many trees resprouting? Did they find much sign of wildlife? Ask students to categorize positive and negative effects on the forest. Review the importance of snags for cavity-nesting birds (see "preserve wildlife and habitat goal" for more information).

    - In the classroom, have students sketch, draw, paint, or write about what they learned and their perspectives on fire.

    - If doing this activity at a different site from the monitoring site, ask students to think about the site they are monitoring and discuss the effects a fire might have at that site.

ACTIVITY 6

Burned Area Scavenger Hunt Worksheet

Name ____

Burned areas can be exciting places to explore. They can also be dangerous. Don't ever go into an area burned by crown fire on a windy day. Listen and watch for falling trees and ash-filled stump or root holes.

See how many of these things you can find in the burned forest. Check them off as you go:

1. ____ Find a place where the fire burned in the tree crowns

2. ____ Find a place where the fire only burned on the ground in grass, shrubs, or needles

3. ____ Find a tree cone. Can you tell what species it is? ______________________________

4. ____ Find a shrub or small plant that sprouted after the fire. How can you tell it was burned?
   ____

5. ____ Find a tree that burned but did not die. What kind of tree is it? _________ How can you tell it burned? ____

6. ____ Find a tree killed by fire. What does the tree look like now? Draw the tree on the back.

7. ____ Find a "snag." Do you see signs of insects or birds at this tree? Describe what you see.

8. ____ Find a place where an animal was feeding. What was it feeding on – an animal, grass, shrub, or tree? __________ How can you tell? _________

9. ____ Find animal tracks. Draw them on the back. What kind of animal made them?
   ____

10. ____ Find animal scat. Draw it on the back. What kind of animal left it there?
   ____

11. ____ Find a place where an animal made a hole in a tree. How big is the hole?

12. ____ Find signs that insects fed on a burned tree. Draw what you see on the back.

Who Lives Here?

In recent years, populations of many native animals have declined in part due to changes in forest conditions, such as fire suppression or removal of old, large trees from the forest. Restoration projects that protect old and large trees, preserve large snags, promote meadows, and support grass and wildflowers will also help to bring back native wildlife that depend on these conditions for their survival.

In this activity, students identify ways plants and animals depend on trees for survival. This is ideally a field activity, but can also be done in a schoolyard where there are a few trees. It is also an activity that can be assigned for students to do at home, or in an area where they can make repeated observations of the same tree. This is an activity that provides important observation skills that are useful when recording photo points for monitoring. It also provides background information for monitoring wildlife conditions, such as tree size, snags, understory cover, and landscape openings.

Objectives

Using observation skills, students will learn that forests provide many different habitats for diverse animals.

Relevant Monitoring Goals

Conserve wildlife populations and habitats

Relevant Monitoring Indicators

landscape openings, bird abundance, butterfly abundance, plant community structure, density and size of living and dead trees, understory plant species composition, understory cover

Materials

- Paper and pencil
- Clipboards or hard writing surface
- Optional: field guides for trees, shrubs, birds, mammals
- Optional: binoculars, hand lenses

Duration
50 minutes

Vocabulary

habitat

snag

cavity-nesting birds

old-growth forest

understory plants

How does wildlife fit in to restoration projects?

Procedure

- Introduce the lesson by telling students they will be observing a tree to see which animals may rely on it for food, shelter, nesting, or in some other way. Explain that these observation skills are important when monitoring, particularly when recording data related to photo points.

- Have students bring a pencil, paper, and clipboard or notebook into the field. You may also want to bring field guides and/or binoculars or hand lenses for students to share.

- Prior to going into the field, discuss with students the importance of being quiet and still so that they can observe as many different kinds of animals as possible.

- Students can work in pairs or small teams to observe a tree. They should look for holes in the bark of trees, chewed plants or bark, animal scat, animal tracks, nests, seed caches, invertebrates beneath leaves and needles, and so on.

- Have students record what they see and hear. Have them identify plants, animals, scat, and other signs of wildlife that they find. Hand lenses can be used for looking at smaller invertebrates. Binoculars can be used for observing birds or mammals higher up. Have students draw what they see.

- Have students organize their observations and present them to the other groups. This can be done in the field so that other students can observe what each group found, or back in the classroom.

- Discuss how the restoration project may affect wildlife habitat: Will it provide new habitats? Will it preserve existing habitats? Will it provide a greater diversity of habitats than before? Are there wildlife corridors created within the project?

- Discuss the indicators students are monitoring for the CFRP project: which of these indicators provide information about habitat conditions for wildlife?

Possible Extension

Many animals require trees and plants of different "height classes," such as grasses, shrubs, and trees. Look around the site and record if these types are present in the following table:

A. 3 or more height classes (grass, shrubs, and trees present)	B. 2 height classes present (mostly trees)	C. 1 height class present (grasses and herbs only)	D. 1 height class, mostly sparse vegetation
Excellent	Good	Fair	Poor

Is this an excellent, good, fair, or poor site for wildlife habitat based on the height classes present? ____________________

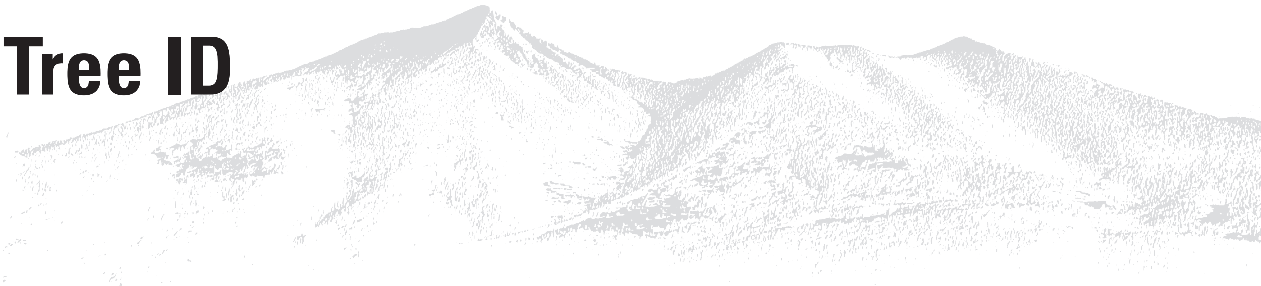
Wildlife also require many different kinds of plants for food. Look at the different species of plants (grasses, forbs, shrubs, trees), and record how many you can find according to the following table:

A. >20 plant species	B. 15-19 plant species	C. 5-14 plant species	D. 0-5 plant species
Excellent	Good	Fair	Poor

Is this an excellent, good, fair, or poor site for wildlife habitat based on the number of plant species present? ____________________

Think of 3 reasons why it is important to set aside areas for wildlife in a forest restoration project?

Tree ID



One goal of restoration is to reduce the numbers of non-native plants and animals that occur in the forest. A second, related goal is to protect and increase native plants, so that their numbers and patterns resemble historic forests. This activity will help students learn to identify some of the native trees and shrubs common to southwest forests. This is ideally a field activity, but it can also be adapted to the classroom. As a field activity, this is a good introduction to basic skills students will need to collect monitoring data for density and size of live and dead trees, understory cover, and understory plant species composition.

Objectives

Students will learn basic skills that can be used to identify common trees and plants. They will learn basic characteristics of plants and will be introduced to using field guides to identify plants.

Relevant Monitoring Goals

change fire regimes, preserve old and large trees, conserve wildlife populations and habitats, conserve and protect riparian communities

Materials

- 300-foot tape measure, 50-foot tape measure, pin flags, metal stakes or rebar (two for each transect line)
- Paper and pencil
- Clipboards or hard writing surface
- Field guides for trees, shrubs, and wildflowers

Duration

50 minutes

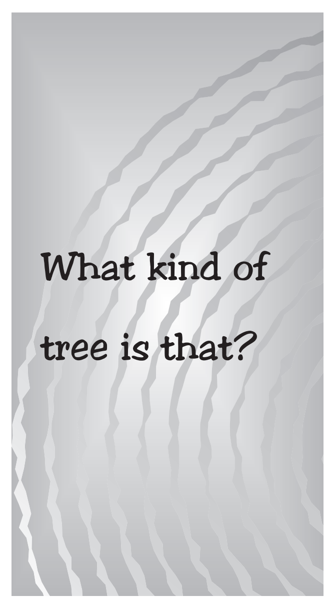
Vocabulary

tree

shrub

grass

forb



Procedure

1. Introduce the lesson by explaining that students will learn some of the basic observations necessary to identify common plants.

2. Take students into the field and have them establish large plots on transects. To do this, follow the instructions in Handbook 4, or in the box at right.

3. In the first plot, have students refer to their field guides to determine the number of different trees, shrubs, grasses, and forbs located within the plot. (If adapting to the classroom, bring in specimens of different trees, shrubs, grasses, and forbs that students can identify. These should be species they can find in the project area. Students can begin by classifying each plant as a tree, shrub, grass, or forb, and then continue with the remaining steps.)

4. Next have students identify each tree and shrub by species. They can use field guides to do this.

5. Optional: have students identify grasses and forbs to family, genus, or species. Many grasses are difficult or impossible to identify to species without flowers and a microscope or hand lens, so you may want to have students use broader systems of classification for these plant types. You may want to contact a local botanist to teach identification skills or to talk to the class about what different species of plants can tell us about an ecosystem.

Setting Up Transects:

1. Randomly locate the first transect by throwing a stick over your shoulder, and starting the transect where this stick lands.

2. At the beginning of the transect point, walk in a straight line with the tape measure in hand, until you have walked 300 feet.

3. Put transect markers at 0 feet and 300 feet.

4. Lay the tape measure on the ground for the full 300 feet.

Establishing Plots on Transects:

1. Walk to the 50 foot mark of the transect.

2. Run a second tape measure perpendicular to the transect for 15-feet on each side of the transect line (30 feet total).

3. Mark each end of the 30 feet with a pin flag.

4. Walk another 30 feet (to the 80 foot mark of the transect), and repeat steps 2-3. The four pin flags will mark the corners of the first plot.

5. Establish plots at 50, 100, 150, 200, 250, and 300 feet, for a total of 6 plots.

6. If combining this lesson with a day of gathering monitoring data, have students use their newly gained skills to determine the "density and size of trees," "seedling density," "understory cover," and/or "understory plant species composition."

Possible Extension: Determining Tree Size Structure

Duration
40 minutes

Vocabulary
size class
tree size structure
seedling
sapling
adult tree

Ponderosa pine forests used to have trees of all ages. Tree size structure tells us how many trees there are of different sizes. Every forest type has a characteristic tree size structure that was typical of natural conditions. The structure would change somewhat with changing conditions, such as climate or disturbances like fire, but would tend toward that typical structure with time.

Ponderosa pine forests, for example, typically had trees in all age classes. In other words, there were young, middle-aged, and mature trees. Trees can grow at different rates, and tree size isn't always a reflection of tree age. But for ponderosa pines in the Southwest before human activities changed forest structure so dramatically, there was a good relationship between age and size.

Restoration projects can learn what the current tree size structure of the site is, and use the knowledge of what the past natural structure was to help set restoration targets. Forests that have a size structure similar to the historic conditions of that forest are more resilient to disturbances than those that are far from their natural state.

In many ponderosa pine forests today, there are many small trees and few large trees. Thinning should return the structure of the forest so that it more closely resembles its historical distribution. Graphs are useful visual aids in understanding forest structure. Graphs charted before tree thinning will have many more trees at the left side of the graph, in the smaller size categories. The graph of tree size after thinning should have fewer seedlings and saplings and more trees in the larger size category.

One measure of restoration success involves a comparison of the graphs of trees size before and after thinning treatments. This extension allows students to analyze data they have gathered for the indicator "Density and size of trees." It requires that students have already collected data, or that they collect this data as part of their training in monitoring methods. Details of how to collect data are found in Handbook 4.

Objectives

Students will learn historic and current forest structures in ponderosa pine forests. They will learn to analyze data by organizing data into categories and graphing the data.

Relevant Monitoring Goals

change fire regimes, preserve old and large trees, conserve wildlife populations and habitats

Materials

- Pencil
- Photocopies of data sheets for Density and Size of Trees
- Photocopies of graph or blank graph paper

Preparation

You will want to organize data sheets prior to this activity, so that only the "Density and Size of Trees" data sheet is used. Make copies of the data sheet. Don't have students work with originals. You may also need to modify the sample table and graphs if there were other species of trees in the project area, or if there are many more trees (usually in a pre-treatment site) than will fit on the sample graphs.

Procedure

1. Introduce the lesson by telling students they will be analyzing data they have already collected in the field.

2. Explain that tree size structure tells us how many trees there are of different sizes, and discuss tree size structure common to the type of forest you are working in. Tell the students that they will use the data they collected by measuring trees in plots to determine the tree size structure of the project area.

3. Explain that they will do this by graphing the number of seedlings, saplings, and adult trees.

4. Have students create a hypothesis for what they think they will find. (Will they find all ages, a single age class, or some other combination?)

5. Break students into groups of 2-3 students.

6. Pass out copies of data sheets that they completed in the field. Have students organize this data into a spreadsheet on a computer or use photocopies of the table below. Students can make tally marks as they sort through the data.

7. Have students use the data they have compiled to make a graph of the number of seedlings, saplings, and adult trees of ponderosa pine trees. Students should use the graph below or create their own on graph paper or on a spreadsheet.

8. Have students repeat step 6 for pinyon and then juniper trees (or other species that were in the project area).

9. Next, have students make graphs with the total numbers of seedlings, saplings, and adult trees for all species combined.

10. Have students compare their graphs. Make sure that graphs are correct. (They should all be identical if using the same data.)

11. Ask students to describe the shape of their graph. Does it form a specific curve or line? What does the graph tell them about each species?

Additional Discussion Points

- Have students think back to when they collected data in the forest. Have them recollect things they learned about the size of different trees. Ask students whether tree size is always an accurate estimate of tree age. Have students explain why or why not.

- In historic ponderosa pine forests, many of the small trees would have been removed by light fires. There may also have been "bumps" in numbers in the larger size classes, since ponderosa pine sometimes regenerated in groups when climate conditions were favorable at various times in the past. The graph for these forests might therefore have had few trees on the left side of the graph, and bumps in the curves for larger size classes. The curve formed for this forest would not be very steep.

  In contemporary forests, fires have been suppressed and there are many more seedlings, saplings, and small adult trees. This makes a steep curve starting high up on the left hand side. This kind of curve represents a forest with a high vulnerability to destructive fire.

  Ask students whether their graphs look like this now? If so, ask them how they think restoration might make the size curve more nearly resemble the historic forest. Or, if the treatment has already been completed, have students compare graphs from data sets before and after the treatment.

- Ask students what effects the current size structure might have on fire? On wildlife?

ACTIVITY 8

Tree ID/Tree Size Structure Extension

Tree Size Structure Table

Species	Category	Total Number at Site
Ponderosa Pine	Seedling	
	Sapling	
	Adult Tree 5-8" diameter	
	Adult Tree 8-11" diameter	
	Adult Tree 11-14" diameter	
	Adult Tree 14-17" diameter	
	Adult Tree > 17" diameter	

Pinyon pine	Seedling	
	Adult Tree < 5" diameter	
	Adult Tree 5-8" diameter	
	Adult Tree 8-11" diameter	
	Adult Tree 11-14" diameter	
	Adult Tree 14-17" diameter	
	Adult Tree > 17" diameter	

One-seed juniper	Seedling	
	Adult Tree < 5" diameter	
	Adult Tree 5-8" diameter	
	Adult Tree 8-11" diameter	
	Adult Tree 11-14" diameter	
	Adult Tree 14-17" diameter	
	Adult Tree > 17" diameter	

ACTIVITY 8

Tree ID/Tree Size Structure Extension

Tree Size Structure Graphs

	10	Ponderosa pine						
	9							
	8							
	7							
# of trees	6							
	5							
	4							
	3							
	2							
	1							
	0							
		Seedlings	saplings	5-8”	8-11”	11-14”	14-17”	>17”

	10	Pinyon pine						
	9							
	8							
	7							
# of trees	6							
	5							
	4							
	3							
	2							
	1							
	0							
		Seedlings	<5” adult	5-8”	8-11”	11-14”	14-17”	>17”

ACTIVITY 8

Tree ID/Tree Size Structure Extension (continued)

Tree Size Structure Graphs

	10	One-seed juniper						
	9							
	8							
	7							
# of trees	6							
	5							
	4							
	3							
	2							
	1							
	0							
		Seedlings	<5” adult	5-8”	8-11”	11-14”	14-17”	>17”

	10	All Species combined						
	9							
	8							
	7							
# of trees	6							
	5							
	4							
	3							
	2							
	1							
	0							
		Seedlings	saplings or <5” adult	5-8”	8-11”	11-14”	14-17”	>17”

What's Growing Up?

Restoration often seeks to change the structure of the forest, for example by altering the number, age, and arrangement of plants and trees. This change in structure helps support the reintroduction of fire and also provides more favorable conditions for native plants and animals. Such restoration principles often incorporate both theory and scientific evidence. One such principle is that changing the amount and arrangement of canopy cover will result in changes in understory plant cover. For example, scientists believe that in areas where there is a decreased canopy cover, more light will reach the ground, and the understory plant cover should increase. Evidence supports this assumption, but there are also cases where this relationship might not occur. For example, understory plant cover might not increase because the soil is damaged in some way or non-native species may outcompete native plants.

In this activity, students compare data between understory plant cover and canopy cover to test a principle of ecological restoration and plant competition. Students will examine the principle that if canopies are more open, more plants will grow on the ground. They also will discuss other factors that affect understory plant growth. This activity can be done in the classroom after field data has been collected.

Objectives

Using basic map-making techniques, students will analyze monitoring data to determine the relationship between canopy cover and understory plant cover. They will be able to explain the implications of this for forest restoration projects.

Relevant Monitoring Goals

Change fire regimes, enhance native plants/reduce non-native plants, conserve wildlife populations and habitats

Relevant Monitoring Indicators

canopy cover, understory plant species composition, understory cover

Duration

50 minutes

Vocabulary

understory plant cover

canopy cover

fire regime

biodiversity

habitat

surface fire

Want to know if there's a relationship between what's growing up above and down below?

Background

One of the goals of restoration in ponderosa pine is to reduce the number of tree crowns that are touching, so that rather than having a fairly dense and continuous canopy of trees, there are areas with grassy openings and areas with tree cover. This has at least two purposes: one is to reduce the threat of crown fires and the second is to create more openings where a greater diversity of understory plants can grow. Reducing the threat of crown fires is part of restoring a more natural fire regime to ponderosa pine forests, in other words, creating conditions that can support frequent surface fires. Creating more openings where understory plants can grow is important for many reasons, including creating conditions that can support a surface fire (the ground vegetation enables surface fires to spread); increasing overall biodiversity in the forest; and creating habitat conditions necessary for many wildlife species.

There is much historical data, from photographs, diaries, and biological evidence, that supports the existence of large openings with thick understory plant cover. By restoring natural canopy cover, restoration will not only achieve the benefits related to changing fire regimes, but also will allow more sunlight to reach the ground, decrease competition for water, and thus allow more species of understory plants to grow. More understory plants can support more animals and ultimately restore the biodiversity in the ecosystem. In this activity, students can compare monitoring data on canopy cover and understory plant cover to see if these relationships bear out in the project area.

Materials

- Acetate (overhead) sheets
- Acetate (overhead) markers in various colors
- Copies of completed data sheets for canopy cover (data sheet G)
- Copies of completed data sheets for understory cover (data sheet K)

Preparation

To complete this activity, you will need completed copies of data sheets. This means that someone should have collected monitoring data at least once. If you do not have this data, you can collect it on a field trip following the methods described in Handbook 4, pages 31-32 (for canopy cover) and pages 44-45 (for understory cover).

Procedure

1. Introduce the lesson by telling students they will be analyzing data they have already collected in the field.

2. Ask students what basic elements plants need to grow (sunlight, water, nutrients). Ask students to explain what factors might negatively affect plant growth (competition for these resources, too much or too little of any one of these resources).

3. Explain that the students are going to create maps that will allow them to examine the relationship between canopy cover and understory plant cover. Tell them that they will look to see if areas where there is high canopy cover (where the forest is fairly dense), have higher or lower understory plant cover (where plant cover on the ground is thick or sparse.) Ask students to generate a hypothesis about what they think they will find. Write this hypothesis on a board or overhead projector.

4. Break students into groups of 2-4. Give each student several sheets of acetate, markers, and photocopies of completed data sheets.

5. Tell students they will create two maps that they will overlay on top of each other. One map will show canopy cover. The second map will show understory plant cover.

6. Ask students to create a key (or legend) for each of the maps they will create. One possible key would be to have different shades of warm colors (yellows, oranges, reds) for different ranges of canopy cover, and then to use cool colors (blues and greens) for different ranges of understory plant cover.

7. Have students use a sheet of acetate (clear plastic) to draw a grid of transects and small plots that represent the arrangement of data they collected. They can do this in black. (Students can refer to Handbook 4 methods, pages 33-34 (for canopy cover) and pages 44-45 (for understory cover) if they do not remember how the transects and plots were arranged.)

8. Using this first sheet of transects and plots, have students create a map of the canopy cover, using their key (legend) and data sheets.

9. Next have students create a map of understory plant cover, using their key (legend) and data sheets.

10. Have students overlay the canopy cover and understory plant cover maps on top of the grid of transects and plots to look for patterns.

11. Discussion Points:
    - What patterns do they see on the maps?
    - From what they can observe, was their hypothesis correct? Have them explain why or why not.
    - Was their hypothesis correct across the whole project area, or only in certain spots? Have students explain why this might be.
    - Do they anticipate a change in this relationship after the project is completed? What would the differences be?
    - What other factors might affect the understory plant cover either before or after a project is completed? (Possible answers include grazing effects; soil compaction from vehicles, equipment or cattle; drought; and low soil nutrients)

Possible Extension

Many students and teachers are interested in technology and its applications. The process of making maps on acetate and overlaying them is common to many projects that want to examine relationships between different variables. This technique, while very simple, is the basic foundation of GIS (Geographic Information Systems), which combines different types of spatial data (such as the spatial arrangement of different ranges in canopy cover along transects and the spatial arrangement of different ranges in understory cover along these same transects). GIS combines these different forms of data into one single map. The overlay process thus mimics the GIS system in a low-tech way. If someone associated with the CFRP project (such as a local Forest Service district or other land management agency) has access to GIS technology, you might be able to get someone to visit the classroom and discuss the applications of this technology, such as creating one single map that represents the same information they created in three layers.

Compaction Action

Two similar activities are found in Project Learning Tree, pages 256-257.

Soil is an often overlooked, yet essential, part of the forest. Healthy soil provides a good home for large burrowing animals, earthworms, and microbes and fungi that help decompose dead wood and needles and help plants absorb nutrients and water. Healthy soil is also soft and porous enough to allow rainwater to easily reach tree roots. Restoration projects should be careful not to harm the soil and its ability to absorb rainfall or provide habitat for animals and microbes.

In this activity, students will look at the effects of equipment or roads on soil. This is ideally a field activity, but can also be done in a schoolyard where there is soil of different conditions.

Duration:
40 minutes

Vocabulary:
soil compaction
understory plants

Objectives

Students will learn how roads and equipment impact soil. They will understand the importance of soil for plants and microorganisms.

Relevant Monitoring Goals

conserve soil resources

Relevant Monitoring Indicators

soil compaction, understory cover

Materials

- 6-30 tin (soup) cans with tops and bottoms removed (all tin cans should be the same size)
- Water
- 6 or more watches with a second hand or timers
- Calculators
- Clipboards or hard writing surface
- Copies of data sheet
- Optional: hand lenses, plant identification guides, invertebrate identification guides

Wonder what's underfoot?

Preparation

It may be helpful to visit the site for this activity in advance to identify locations for each of the six groups. This is not essential, however. It may also be helpful to prepare data sheets (on page 77) that students can use to record information. You may also want to prepare small cards or pieces of paper with a description of each of the six sites.

Procedure

1. Introduce the lesson by telling students they will be looking at the effects of heavy equipment and roads on soil, plants, and microorganisms.

2. Explain that six teams of students will be looking at soil compaction by measuring the rate that water percolates into the soil at different sites. (You may want to change these sites to better fit the specifics of your project area.) The sites are as follows:
   - An area beneath trees where there are needles and leaves where no vehicles have driven
   - An open area between trees where no vehicles have driven
   - An area beneath trees where there are needles and leaves and where equipment or vehicles have driven
   - An open area where equipment or vehicles have driven
   - An area at the side of a road
   - An area in the middle of a road

3. Have students create hypotheses for which areas will have the greatest soil compaction and have them explain why.

4. Divide the students into six teams. Assign each team to one of the six sites and have students complete the following exercise:
   - b. Go to the site and record what the ground looks like. Make a sketch of the vegetation that may be growing in the area and use terms such as: grasses, forbs, litter, and bare soil to describe the site. Optional: use field guides to identify plants growing on this site.
   - c. Take the tin can and twist it into the ground so that it is about 1 inch below ground (enough so that water will not leak out the bottom). For cans with grooves in the middle of the can (many soup or vegetable cans have these), the students can put the can into the ground just to the top of the first groove.
   - d. Fill the tin can with water.
   - e. Record how long it takes for the water to penetrate the soil in the table at the end of this activity. (For compact soils or soils with heavy clays, it may take 5-15 minutes or more for water to completely filter.)

f. Repeat this 4 more times at the same site. Spread the measurements out by about 5 feet. (Students can do all trials at the same time if there are enough cans and timers.)

g. Add up each of these times and divide the total time by 5 to get the average.

h. While still at the area, use a hand lens to look for any microorganisms that may be living in the soil. Turn over leaves, needles, and logs to see if there are any invertebrates at the site. Record this as part of the site description. Make sure to return logs to their original position, and cover soil with litter again. Optional: use field guides to identify any organisms found.

5. Have each group present their findings to the class as a whole.

6. Rank each area from fastest to slowest to percolate the soil. Were the students' hypotheses correct?

7. Discuss how restoration projects might positively and/or negatively impact soil based on these findings. Some discussion points might include:
   - Were there different kinds of plants growing at the site? Were any of these plant species exotic (non-native)?
   - Think of three things that might lead to soil compaction at a site.
   - Did anyone observe gullies from rain or other types of erosion?
   - What effect might compacted soil have on the forest? How would it affect plants and animals? How might it affect trees?
   - You might also discuss how performing repeated measurements affects the accuracy of data.

8. Discuss how data from monitoring bare soil and understory cover might provide information related to soil compaction.

Possible Extension:
Soil Erosion

In preparation for this extension, you will want to talk to your CFRP project partners to discuss the location of the activity. Have students walk transects within or next to the monitoring site, depending on what your project partners decide, using the following procedure:

- Have students randomly locate the beginning of the first transect by tossing a stick over their shoulder.
- Have students lay out a 100-foot transect.
- Every 10 feet on the transect, have students describe the soil according to the table below (Refer to Handbook 4, Understory Cover, for details on monitoring percent cover in an area.)
- Students should record the soil condition on a data sheet at the end of this activity.
- Have students repeat this exercise with 6 additional transects, evenly spaced and parallel to the first transect. Transects should be spaced every 100 feet.

A. Soil intact with at least 75% covering of litter or understory cover	B. Soil intact with 50-75% covering of litter or understory cover	C. Soil mostly intact, but more than 50% bare soil or some signs of soil erosion	D. Significant signs of soil movement, such as erosion, mass wasting or deep gullies
Excellent	Good	Fair	Poor

- In the field or back in the class, have students analyze the data they collected. What percent of the site sampled was in excellent condition? What percent in good condition? Fair? Poor?
- Have the students create a diagram of the soil conditions at the site. Discuss areas where soil conditions were excellent or poor. Have students suggest possible causes of these conditions.
- Overall, is the soil at this site excellent, good, fair, or poor?

ACTIVITY 10

Soil Compaction Data Sheet

Soil Compaction Data Sheet

Site Description:	
Trial #	**Time to percolate (in minutes and seconds)**
Trial 1	
Trial 2	
Trial 3	
Trial 4	
Trial 5	
Total Time for all 5 Trials (Add times for Trials 1-5)	
Average Time (Divide Total by 5)	

ACTIVITY 10
Soil Erosion Data Sheet

Soil Erosion Data Sheet

Site name ______________________________ Location ______________________

Observer(s) ______________________________ Date: ________________________

*Use the following symbols for soil conditions:

E = Excellent (soil intact with at least 75% covering of litter or understory cover)
G = Good (soil intact with 50-75% covering of litter or understory cover)
F = Fair (soil mostly intact, but more than 50% bare soil or some signs of soil erosion)
P = Poor (significant signs of soil movement, such as erosion, mass wasting, or deep gullies)

Transect #	Point on Transect	Soil Condition*
1	10 feet	
	20 feet	
	30 feet	
	40 feet	
	50 feet	
	60 feet	
	70 feet	
	80 feet	
	90 feet	
	100 feet	
2	10 feet	
	20 feet	
	30 feet	
	40 feet	
	50 feet	
	60 feet	
	70 feet	
	80 feet	
	90 feet	
	100 feet	
3	10 feet	
	20 feet	
	30 feet	
	40 feet	
	50 feet	
	60 feet	
	70 feet	
	80 feet	
	90 feet	
	100 feet	

Transect #	Point on Transect	Soil Condition*
4	10 feet	
	20 feet	
	30 feet	
	40 feet	
	50 feet	
	60 feet	
	70 feet	
	80 feet	
	90 feet	
	100 feet	
5	10 feet	
	20 feet	
	30 feet	
	40 feet	
	50 feet	
	60 feet	
	70 feet	
	80 feet	
	90 feet	
	100 feet	
6	10 feet	
	20 feet	
	30 feet	
	40 feet	
	50 feet	
	60 feet	
	70 feet	
	80 feet	
	90 feet	
	100 feet	

ACTIVITY 10

Soil Erosion Diagram Sheet :

Soil Erosion Diagram Sheet

Site name ______________________________ Location ______________________

Observer(s) ______________________________ Date: ________________________

Sketch map of site

Use the following symbols for soil conditions. Make a diagram showing the locations of different soil conditions along transects as recorded on the data sheet.

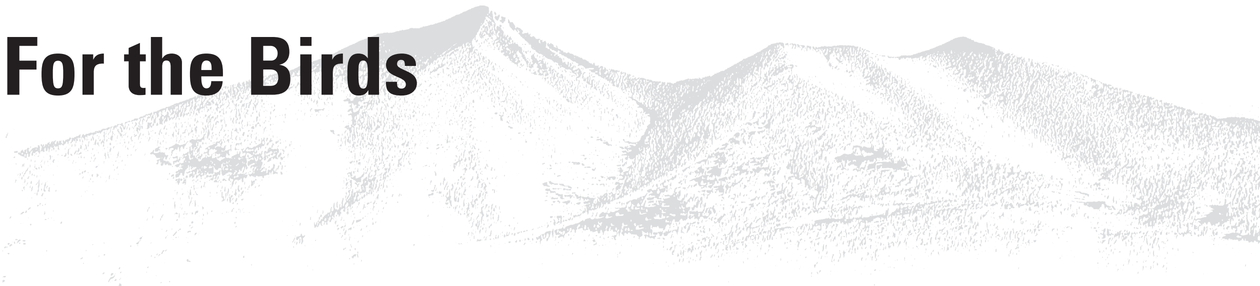
E = Excellent (soil intact with at least 75% covering of litter or understory cover)
G = Good (soil intact with 50-75% covering of litter or understory cover)
F = Fair (soil mostly intact, but more than 50% bare soil or some signs of soil erosion)
P = Poor (significant signs of soil movement, such as erosion, mass wasting, or deep gullies)

Note abbreviation used:____

— Make copies of this sheet for additional transect and/or plots —

ACTIVITY 11

For the Birds



By design, restoration causes changes to the physical environment of a forest. These changes can affect different species of wildlife in different ways. A more open forest, with more patchy meadows, will provide a better habitat for the many native species that are adapted to the historic forest structure. The bright Western bluebird is one example of a species that thrives in restored forests.

The big changes that accompany forest restoration may cause some temporary unwanted impacts on wildlife. For example, restoration may allow brown-headed cowbirds to take advantage of other birds while there are newly created patch edges. In this activity, students will learn about the potential for effects of forest restoration on cowbirds and other bird species. This activity involves data from the "landscape openings" indicator in Handbook 4, with possible classroom and field extensions.

Duration:
50 minutes

Vocabulary:

native species
brood parasite
host
forest edges
treatment
endangered species

Objectives

Students will learn how forest restoration projects may have short term negative effects. They will learn some of the biology of the brown-headed cowbird and will understand the role of a brood parasite in forest ecology. They will also learn that care must be taken to minimize short-term unfavorable impacts of forest restoration.

Relevant Monitoring Goals

conserve wildlife populations and habitats

Relevant Monitoring Indicators

bird abundance and species composition, landscape openings

Background

Brown-headed cowbirds thrive near forest edges, where they can have access to the nests of other birds. Cowbirds are brood parasites, which means that they use other bird species to help them reproduce. Cowbirds do this by laying their eggs in other bird species' nests and letting these other birds raise and feed their nestlings. They accomplish this by watching the nests of other

Want to look at a case of how forest restoration might affect wildlife?

Two brown-headed cowbird eggs "snuck" into another bird species' nest.

birds. When the adults fly away from the nest, the female cowbird quickly lays an egg in the existing nest. Female cowbirds need to be quick to avoid detection from the other birds. They can lay their eggs in 10-30 seconds. Once eggs are laid in one nest, the female cowbird continues to lay eggs in other nests within the forest. One female can lay 20-40 eggs over 4-6 weeks.

Baby cowbirds also hatch very quickly, in 11-12 days. This is typically faster than the other bird species. Baby cowbirds are also usually larger than the species whose nests they occupy. The baby cowbirds can then push eggs or babies of other species out of the nest so that the adult birds will only feed and raise the cowbird.

Some of the host birds have evolved defenses against the cowbird. Some of these birds push the cowbird eggs out of the nest. Others puncture the egg. Still others pick up the eggs in their beaks and drop them away from the nest. Other birds do not have any adaptation to the cowbird. These species of bird will raise the cowbirds.

The process of restoring patches of forest, which have boundaries and create edges in the forest, will provide more edge-habitats that will make other species of birds' nests more accessible to the cowbird. As more of the landscape is restored, there will be fewer edges between forest patches. In the long-run, restoration across the landscape will allow the native wildlife species, which are adapted to more natural structures of the forest, to thrive.

Materials

- Acetate (overhead or clear plastic) sheets, approximately 8.5 x 11 inches in size
- Overhead writing markers in different colors, one of these should be brown
- Photocopies of completed data sheets from the "landscape opening" method (data sheet B in Handbook 4) from before and after treatments (if available). Or photocopies of blank data sheets if monitoring data has not yet been collected.
- Optional: Field guide for North American birds for students to identify brown-headed cowbird and other bird species
- Optional: "Winged Migration" video or DVD; photocopies of completed data sheets from the bird abundance and species composition" method (data sheet C in Handbook 4).

Preparation

This activity will require students to have already collected data on "landscape openings" as part of the monitoring project. Ideally, students will have collected, or have access to, pre- and post-treatment data. If students have not collected this data, then this can be a two-part activity, with the first component being a field activity, and the second part being an analysis on data in the classroom or field. Students can also make a hypothetical map of post-treatment data based on what the project calls for in its treatment. For this latter option, you may need to talk to the project manager or Forest Service personnel help with analysis of the project prescription.

Procedure:

1. Introduce the lesson by explaining that students are going to evaluate potential effects of forest restoration on wildlife species. They will do this by creating maps of landscape openings and edges in the forest restoration project area. They will use these maps to evaluate the length of edges before the project began and the length of edges created by the project. They will interpret this information in the context of the potential effects the restoration project might have on both the cowbird, which thrives on forest edges, and the other bird species the cowbird affects.

2. Ask students to define a parasite. Ask them to make an educated guess as to what a brood parasite might be. Ask students to come up with reasons why a brood parasite might have evolved, and what other birds might do to adapt to a brood parasite.

3. Explain that students will collect data on landscape openings in the project area. (If students have already collected data, then they will skip this step.) They will do this by following the method in Handbook 4, page 25, for landscape openings.

4. Students should mark the location of the following features along transects:

   - Project boundaries (B)
   - Roads (R)
   - Openings or meadows (OM)
   - Forest types (pinyon/juniper (PJ), ponderosa pine (PP))
   - Streams, riparian areas, or wetlands areas (W)
   - Seedling and sapling thickets (SST)
   - Oak thickets (O)

   Students can create their own symbols if they want, or they may use the letter abbreviations to mark each boundary.

5. Using the data collected in Step 3 or in a previous monitoring site visit, students should re-create the transects on a sheet of acetate (clear plastic). Break students into groups and have them map the landscape features onto the acetate. They should make these maps to scale so that they can tell how many feet each area encompasses. They can use any color except brown for the symbols on the transects.

6. Give each group a second sheet of acetate. Have them trace the boundaries of each vegetation type. So, for example, they should draw a line around meadow areas, pinyon-juniper woodlands, or wetland boundaries.

7. Next have students place a third sheet of acetate over the first two. With a brown marker, have students trace the outline of any landscape feature that creates an edge. So, for example, project boundaries, roads, openings or meadows, or changes in forest types all create edges.

8. Have students calculate the total number of feet of edge that are created by the project.

9. If the project has already been treated, and students have collected pre- and post-treatment data, have them repeat steps 3-8 with post-treatment data.

10. Have students compare the extent of edges, represented by feet, that are present in the restoration area before and after the project.

11. Based on students' findings from this activity, discuss how restoration projects might positively and/or negatively impact bird species. Some discussion points might include:

    - Does the project increase the length of edges in the forest?
    - How will an increase in edges affect bird species? How will it affect the brown-headed cowbird? How will it affect other bird species?
    - Ask students to investigate whether there are any threatened or endangered species that might nest in the area. Ask students whether the cowbird might affect this species. (Remind students that cowbirds generally are parasitic only on nests of birds that are smaller than the cowbird.) Discuss how brood parasitism may affect threatened or endangered species more than other native bird species.
    - Are there ways that projects might be designed to minimize negative effects? What might those be? Optional: have students re-design the project treatment so that it minimizes edge effects. Have students discuss the pros and cons of alternative treatments in terms of fire or other wildlife considerations.
    - Remind students that brown-headed cowbirds are native birds, just like many other bird species that live in the forest. Have students compare the parasitic behavior of the cowbird to the predatory behavior of a hawk or eagle. What are some of the human/emotional responses students have to the cowbird's behavior? How is the cowbird's behavior similar or different to the behavior of a hawk? To the bald eagle?

Possible Extensions

Extension 1: The video "Winged Migration" documents a newly-hatched cowbird at work. The film shows this baby rolling the other eggs out of the nest, demonstrating the behavior of a brood parasite. This documentation is in the first segment of the film. You could show the clip as part of the discussion or show more of the film to discuss the importance of habitats to both migrating and resident birds, and how restoration projects might impact these different species.

Extension 2: Take students into the field and walk the edges created by the forest restoration project. Have them look for nests of any kind in trees. Or, if monitoring bird species composition, have students look at the number of species in the project area, and discuss how many of these species may have nests that could be affected by cowbirds.

Bosque Boogie

This is a classroom activity that can be done indoors or outside in the schoolyard. In this activity, students will create models of the bosque system and will experiment with the germination of cottonwood seedlings under different flooding patterns. Note: There is an excellent modeling activity in The Bosque Education Guide, pages 162-189 that models the bosque in the past, present and future and incorporates models of cottonwood regeneration.

Many forests and other natural communities evolved with disturbances such as fire and flooding. Cottonwood bosques along rivers were one of these communities. Periodic flooding cleared away leaves and other debris and wet the surface of sandy soils so that cottonwood seeds could germinate. Many human activities, such as dam building and diversion of water for agriculture, have changed the flooding patterns on rivers. Restoration of cottonwood bosques may require artificial flooding, in order to re-create conditions that will allow new cottonwood seedlings to grow.

Objectives

Students will learn about historic and current flooding regimes in the bosque woodland. They will understand the conditions required for cottonwood seedlings to germinate, and will be able to apply this knowledge to issues of restoration along the Rio Grande.

Relevant Monitoring Goals

conserve and protect riparian communities

Relevant Monitoring Indicators

density and size of live trees, seedling density, classification of plant community structure

Duration:
50 minutes

Vocabulary:

germinate
flooding regime
overbank flooding
seedling
water table

Wonder how flooding affects cottonwood growth?

Materials

- 4 large rectangular tubs, approximately 24" square and 10" deep
- Sandy soil
- Small trowel
- Colored paper to represent houses, agricultural fields, levees
- Cottonwood seeds
- Water

Preparation

There are a number of ways to create the bosque models that will be used for this activity. One simple way is to use plastic washtubs that can be filled with sand and "flooded" to varying degrees. You will want to fill the plastic tubs in advance with sandy soil.

Procedure

1. Introduce the lesson by telling students they will be creating models of the Rio Grande to understand the conditions cottonwood trees need to germinate.

2. Start out with one plastic tub filled with sand. Have students create a general model of what the Rio Grande looks like today. If students have visited the project site, have them make a model of this area. Have students incorporate the following items into the model. The river, tributaries, sand bars, and ditches can be made by digging channels into the sand with a small trowel.

    - The Rio Grande
    - Any relevant tributaries
    - Sand bars
    - Any irrigation ditches
    - Levees
    - Agricultural fields
    - Houses
    - Locations of monitoring transects and plots

3. Give students a pre-determined number of cottonwood seeds (at least 30 seeds total). Explain that cottonwood seeds are dispersed by the wind.

4. Have students blow the seeds onto the model and see where they land.

5. Next have students determine how many of these seeds could actually germinate and survive. (Seeds that land in the river, tributaries, irrigation ditches, levees, houses, or agricultural ditches would not germinate and survive.)

6. Ask students to calculate the percentage of seeds that could germinate. (For example, if 3 seeds landed in the floodplain of the river, and 30 seeds were thrown, then 3/30 or 10% of seeds could germinate.)

7. Discuss what other factors might affect whether these seeds will germinate. Explain that cottonwoods need bare soil, wet soil, and sunlight in order to germinate. Have students look at the model to see if this would reduce further the number of seeds that can germinate.

8. Introduce the concept of overbank flooding. Explain that before major changes were made to the Rio Grande (through the creation of irrigation ditches, levies, jetty jacks, and other water diversions), the banks of the river would flood. Tell students that cottonwoods are adapted to this flooding regime, and that they rely on flooding for germination. Explain that overbank flooding provided at least two purposes: 1) it moved shrubs, cattails and other riparian vegetation downstream, thereby creating open spaces where cottonwood seeds could germinate; 2) it provided soil that was wet enough for the cottonwood seeds to germinate.

9. Explain that human influences have affected the timing and extent of flooding in the bosque. Break students into 3 groups and give them the remaining three tubs filled with sand and 30 seeds per group. Tell them that they will each be testing the number of seeds that germinate under different flooding regimes:

    a. Flooding Regime 1: Overbank flooding (represented by complete flooding of the sandbox so that sand is completely saturated)

    b. Flooding Regime 2: High water table (represented by moist sand that is not completely saturated)

    c. Flooding Regime 3: Controlled water flow. No flooding. Reduced water table. (represented by dry sand)

10. Have students create hypotheses for which flooding regime will have the greatest germination of cottonwood seeds and have them explain their thinking for these hypotheses.

11. Have each student take an equal number of cottonwood seeds (a total of 30 per group). As in Step 4, have students blow the seeds into the sand box.

12. Leave the seeds in a sunny window or area where there is good, natural light for approximately 12 hours (the length of time cottonwood seeds are supposed to need to germinate).

13. After 12 or more hours, check the sand box to see how many seeds germinated under each flood regime.

14. As in Step 6, ask each group to calculate the percentage of seeds that germinated under each flooding condition.

15. Ask students from each group to present their findings to the class as a whole. Request that students give explanations that relate to cottonwoods' needs for germination (bare soil, sunlight, and wet soil).

16. Were the students' hypotheses correct? Have students explain why or why not.

17. Discuss how restoration projects might positively and/or negatively impact cottonwood germination. Some discussion points might include:

    - Does the project remove non-native plants and create openings that provide bare soil?

    - Does the project create openings that allow full sunlight to hit the ground?

    - Will cottonwoods germinate in areas that are not flooded (such as areas that receive rainfall only)?

    - Are there any plans in the project to re-create overbank flooding within the bosque? If so are there other conditions present (bare soil, ample sunlight) so that cottonwoods could germinate?

    - If the project re-creates overbank flooding once, will this be enough to maintain the cottonwood forest over time? What other factors will affect this? (Human uses of water, continued flooding, other plant species that grow into open spaces)

ACTIVITY 13

What's in a Watershed?

Adapted from The Streamkeeper's Field Guide, pages 18-42

Most restoration projects are located in a patch of forest that is part of a much larger watershed. Ideally, many restoration projects will collectively contribute to overall restoration across the landscape. Yet restoration activities in a small area still can impact water, soil, plants and animals far downstream from where these actions take place. This activity combines scientific concepts of watersheds and watershed health with human influences that affect these. It is designed to be a research activity so that students learn to gather information from a variety of sources and investigate questions. It provides information on a broad scale that can encompass a CFRP restoration project.

Objectives

Students will learn some basic characteristics of their watershed. They will learn to delineate a watershed on a topographic map, and will gain experience in gathering information from diverse sources.

Relevant Monitoring Goals

Enhance native plants/reduce non-native plants, conserve wildlife populations and habitats, conserve soil resources, conserve and protect riparian communities

Relevant Monitoring Indicators

understory plant species composition, bird species and abundance, butterfly species and abundance, classification of plant community structure

Materials

- USGS topographic map
- Copies of worksheet
- Optional: plant identification guides, animal identification guides

Duration:

50 minutes

Vocabulary:

watershed

topographic map

delineation

contour lines

aquifer

precipitation

igneous

sedimentary

metamorphic

native and non-native species

threatened and endangered species

Do your students understand the big picture?

Preparation

You will need to obtain a topographic map that encompasses your watershed. To do so, you may contact a local office of the U.S. Geological Survey, or visit the website: terraserver-usa.com to download a free map. (Or you may have students do this as part of the activity.) You may want to look at these maps in advance to determine if you will study an entire watershed or a sub-watershed. If your class is monitoring part of the Rio Grande bosque, you may want to identify a sub-watershed, since the Rio Grande watershed is so large (see box at left).

You also may want to talk to CFRP project partners, especially agency personnel, about sources of information that students may access. Some good sources of local and regional information on watersheds are listed in Appendix 2.

Procedure

1. Introduce the concept of a watershed.

2. Explain that students will be identifying their watershed and will be researching the characteristics of this watershed in order to better understand how restoration actions fit into a larger landscape.

3. Have students identify the watershed that contains the location of the restoration project they are monitoring. They can do this by visiting www.epa.gov/surf/ or by physically examining a topographic map.

4. If physically examining a topographic map, either provide students with a map, or have them obtain a map from one of several sources (the New Mexico USGS District and www.terra-usa.com are two good sources listed in Appendix 2).

5. Explain that the contour lines on the topographic map represent different elevations of land. Have them identify familiar locations on the map and determine the elevations of these places from contour lines.

The Rio Grande Watershed covers a vast area, including:

- Parts of Colorado, New Mexico, and Texas states in the U.S.
- Parts of Chihuahua, Coahuila, Nuevo Leon, Tamaulipas, and Durango states in Mexico

6. To delineate the watershed, have students follow these steps:
   a. Identify the location of the CFRP project on the map
   b. Next, find the lowest elevation point near this location on the map. (Generally, it will be the base of a stream or another body of water. For bosque projects, it will the Rio Grande itself.)
   c. Trace this body of water from its mouth to its tributaries.
   d. At intervals of 1/4 inch to 1 inch (depending on size of watershed), draw lines perpendicular to the stream or river out to the highest point (the contour line that shows the highest elevation). Mark these points with dots.
   e. Repeat steps C and D for each tributary.
   f. When each tributary is finished, connect all the dots, with a dotted line that runs perpendicular to contour lines. This is the watershed boundary.
   g. Make sure that the boundaries make sense.

7. Once the watershed has been delineated, it will be possible for students to answer some of the questions on the worksheet following this exercise under the "watershed overview" section.

8. You may either have students complete this section of the worksheet only and conclude the lesson, or have them continue to identify information about the watershed over the course of several days or as homework.

Possible Extension:

After completing the worksheet in that follows this activity, take students out to investigate the watershed. There are many resources that can help with this, including the Bosque Education Guide, New Mexico Watershed Watch, and the Streamkeeper's Field Guide (see Appendix 2). Watershed investigations can include indicators of stream health, such as macroinvertebrates, stream channelization, bank stability, and structural diversity of vegetation.

ACTIVITY 13
What's in a Watershed

Watershed Inventory
Adapted from The Streamkeeper's Field Guide, pages 38-41

Date _________ Name _________________________ Group __________________

Watershed Name ______________________ USGS quad(s) __________________

****

WATERSHED OVERVIEW

Begins in ____________________________ Flows through ________________________

Ends in ______________________________ (name towns, counties, states, regions, etc.)

Drains into ____ (name body of water)

Approximate Length _________________ Width ________________________________

Headwaters originate from snowmelt ___ rain ___ lakes ___ groundwater ___ springs ___ other ___

Areas underlain by aquifers ____

CLIMATE

Average yearly precipitation 1-3 inches 4-6 inches 7-9 inches > 10 inches

Most of the precipitation is in the form of: rain ___ snow ___ other ___

Most precipitation occurs in month(s) ______________________

Most recent drought _____________ Typical drought frequency__________________

GEOLOGY/TOPOGRAPHY

What geologic processes shaped the watershed? _________________________________

What are some of the rock types? Igneous ___ Sedimentary ___ Metamorphic ___

What are the names of some specific rocks? ______________________________________

What are common soil types? ____

What is the highest point in the watershed? ______________ (in elevation and location)

What is the lowest point in the watershed? _______________ (in elevation and location)

VEGETATION

What are some of the native and non-native plant species in different parts of the watershed?

	Native	Non-native
Ponderosa pine forest		
Pinyon-juniper woodland		
Bosque		

What are reasons for loss of native plant species in each ecosystem?

Ponderosa pine____

Pinyon-juniper woodland ____

Bosque ____

Are there any threatened or endangered plant species? If so, what are they and in which ecosystem(s) are they located?

Threatened/endangered species	Ecosystem(s) where located

How and why were the non-native plant species introduced?

Non-native species	How and why introduced

WILDLIFE

What are some of the native animal species in different parts of the watershed? Are any species threatened or endangered?

	Animal species	Threatened of endangered?
Ponderosa pine forest		
Pinyon-juniper woodland		
Bosque		

Are there any non-native animal species in the watershed? ___________________________

How and why were these species introduced? ______________________________________

CULTURE & LAND USE

Who were the earliest inhabitants within the watershed? _____________________________________

Briefly describe the historic settlement within the watershed __________________________________

____

What are some historic land uses within the watershed? ______________________________________

____

What are some current land uses within the watershed? ______________________________________

____

What percent of the watershed is public land ________% private land ______%

What are some ways the watershed has been altered? (such as through dams, diversions, irrigation ditches, dikes, drained wetlands, etc.)

Type of alteration	Location	Purpose

Where do most people get their water? (such as well or city) ________________________

Where does this water come from? (such as aquifer or river) _____________________

What current or historic land uses have led to the need for restoration? _______________

DEMOGRAPHIC

What is the current watershed population? _____

What was the population 10 years ago? _____ 50 years ago? _____

What is the projected population for 10 years from now? ____ 20 years from now? ____

Other Fun Things to Do

The following are general observations or short activities that students can make when in the field. These can be folded into any of the above activities, or blended into days when students are collecting monitoring data.

Behold, the bark beetle.

Bark beetles can affect both pinyon and ponderosa pine trees. If you are working in an area with either of these tree species, you can look for signs of the beetles. One sign is dead trees, with orange needles still on the branches. Actual signs of beetles can include a yellowish, warty looking sap encrusted on the bark of infested trees, or sawdust material at the edges of holes, particularly in wood that is already on the ground. For trees already on the ground, you can also lift off bark and sometimes see grooves left in the wood by the bark beetles. You might discuss how bark beetles are a natural part of forests, and that they serve important ecological roles. Resources for information about bark beetles are provided in Appendix 2.

Browsing for butterflies.

Some animal species respond very quickly to restoration actions. These are called wildlife indicators. One example of a wildlife indicator is butterflies, which respond to changes in light (by creating openings in the forest) or changes in air temperatures (altered by changes in tree structure and other vegetation changes). Butterflies also can respond to an increase in understory plant cover and understory species composition. You can have students observe the number and diversity of butterflies by using the monitoring method in Handbook 4, page 27. Or you can simply have groups of students sit quietly in different microhabitats (open areas, shady areas, areas with many different plants, areas with only a few plants, areas along roads, areas near water, etc.) for 15 minutes or more, and have them draw or describe the types of butterflies they observe in this time frame. Students can then compare the diversity of species they find in these areas.

Counting the rings.

In many project areas, there will be stumps of ponderosa pine or other trees that have been cut as part of the project or in the past. Have students study these stumps. They can count rings on these trees to estimate the age of the tree when it was cut; they can look for variations in tree ring width and try to determine what might have caused these variations; and they can look for fire scars or beetle infestations. While some trees are easy to observe, others are too roughly cut to make observations with any detail. Sometimes sanding the tree stump with rough sand paper can help increase visibility of tree rings. If you think you might want to have students make these observations, carry some rough grain sandpaper and a hand lens (or two) with you.

Sightings on snags.

Snags – or dead, standing trees – are important for many species of wildlife. Bacteria and fungi feed on bark, causing it to decay. Many insects feed on the decaying bark. Several species of bird, such as sapsuckers or woodpeckers, then feed on these insects. Have students look for signs of beetles and the birds that feed on them. Remind students that snags do provide habitat for many animals and to treat each snag carefully. They can pull off small pieces of bark to make observations (making sure to leave most of the snag intact. Rows of small holes generally signal that sapsuckers have been at work on the tree. Snags are also important for cavity-nesting birds. These birds rely on the rotted wood to make cavities (holes) where they lay their eggs and nest. Some of these birds include northern flickers, house wrens, and mountain bluebirds. Have students look for these birds or signs of them. If you are in the field during the breeding season, have students look quietly for birds from a distance and be careful not to disturb any nesting areas. A field guide may help to identify nests or birds themselves. In addition, look for bird use along older lightning scars in the bark, and dead portions of living trees.

Sniffing for butterscotch.

The sap of ponderosa pine trees is particularly fragrant in the spring and fall months, when sap is moving up and down the tree in greater abundance. Some say the sap smells like butterscotch. Students can smell the sap by sticking their nose into the open areas, or cracks, of ponderosa pine bark. Ask students what it smells like to them.

Where am I?

Many monitoring projects use GPS (Global Positioning System) to mark the locations of transects and photopoints. Students often ask where the information comes from within the GPS. The simplest explanation is the GPS gathers information from different satellites to determine a location or position. Another, more technical way, to explain this is that the GPS "triangulates" information from different satellites. So that students better understand this, you can have three students form a triangle, standing about 20 feet apart from each other. Have a fourth student stand anywhere inside the triangle formed by the three students. Give each of the three triangle-forming students a compass, and ask them to determine the compass direction between where the middle student stands and where the triangle-students are standing. Then have students draw this on paper. Each of the three compass bearings should point to the same direction: to the location of the fourth student. Explain that this is the same concept used by GPS. The GPS unit gets different readings (the compass bearings of the example) for a particular position (the fourth student in the example), and that these give a location in space.

Educational References and Resources

General Education Resources

The **Society for Ecological Restoration** is a useful resource and provides a helpful primer in terms and concepts. See http://www.ser.org/content/ecological_restoration_primer.asp for an overview of restoration & restoration terminology.

The **Ecological Restoration Institute** of Northern Arizona University also provides information on forest restoration at their website: www.eri.nau.edu.

Project Learning Tree, Environmental Education Activity Guide, Pre K-8, produced by the American Forest Foundation, provides nearly 100 activities related to diversity, interrelationships, systems, structure and scale, and patterns of change in forested ecosystems. American Forest Foundation, 1111 19th Street, NW, Washington DC 20036. www.plt.org, 202-463-2462.

Rocky Mountain and Southwest Forests: A field guide to birds, mammals, trees, flowers, and more by John Kricher/Gordon Morrison, from the Peterson Field Guide series, provides a helpful overview of the characteristics, plants, and animals of different forest ecosystems in the Southwest.

Acorn Naturalists, Resources for the Trail and Classroom is an excellent source of reference books, educational resources, field guides and equipment. To obtain a catalog call 1-800-422-8886, or visit their website at www.acornnaturalists.com

C. Finlayson, C. E. Lev, D. O'Connor, and S. Chandler. 1997. **Tools, Trees, and Transformation: A Collection of Restoration Stories from Schools and Community Groups in and around Portland**. Tualatin, OR: The Wetlands Conservancy. This resource provides an overview of a variety of restoration projects that tie together schools and community groups in the Portland, Oregon area. They also give ideas for involving schools in monitoring restoration efforts.

The **Environmental Protection Agency** provides many resources, activities, and links for teachers on several topics, including endangered species and watersheds on its website at: http://www.epa.gov/teachers/curriculum_resources.htm.

The **ForestERA project** (located at http://jan.ucc.nau.edu/~fera-p/), is a project to use comprehensive spatial data sets and modeling tools in order to make landscape scale decisions about restoration. It's an excellent website for students to explore and learn about different principles, aspects, and choices for restoration in the southwest, especially for teachers and students interested in applications of technology in science.

Wildlife

Restoring North America's Birds, Lessons from Landscape Ecology, by Robert A. Askins, 2002, Yale University Press, provides an excellent scientific overview of the effects of different types of logging, fire, and other disturbance on birds of western forest in Chapter 7: Birds of the Western Mountain Slopes.

Produced by Cornell Lab of Ornithology and Thayer Birding Software, the **Guide to Birds of North America** v.3 is an extremely comprehensive CD that contains photographs, habitats, range maps, songs, and identification tips for most birds found in North America. A bird identification window allows you to select color, size, habitat, and other variables that can help you identify unknown birds. There are more than 700 quizzes, from easy to difficult, that can be formatted into multiple choice, fill-in-the-blank, or flash cards quizzes. Thayer also produces a Birds of New Mexico CD, which contains 320 birds, or Birds of the Southwest, which contains 362 species. CDs are available on-line at www.thayerbirding.com, by calling 800-865-2473, or writing 809 Walkerbilt Rd, Suite 4, Naples FL 34110-1511.

Tyler, Hamilton A. 1991. **Pueblo Birds & Myths**. Northland Publishing Co., Inc, P.O. Box N, Flagstaff, AZ 86002. This is an excellent resource for any Pueblo tribe who wants to incorporate traditional knowledge and stories about culturally important birds into youth education or monitoring projects. It contains a brief overview of Pueblo classification of birds and then provides mythology about various birds such "Birds of the Sun," (macaws, parrots and parakeets), "Birds of the Sky" (eagles, ospreys, and large hawks), "Rain Birds" (swallows, swifts, hummingbirds, and doves) "Water Birds" (ducks, snipes, killdeer, and sandhill cranes) and others.

Partners in Flight has an informative website (www.partnersinflight.org) with lists of organizations involved in bird conservation. They also list many helpful birding resources for educators at www.partnersinflight.org/birdbib/. Or order A Guide to Bird Education Resources, Migratory Birds of the Americas: An Annotated Bibliography, which contains 128 pages with sections on curricula, lessons, activities, workshops, books, videos, and more. The guide can be ordered by calling 800-850-2473 or writing the American Birding Association Sales, P.O. Box 6599, Colorado Springs, CO 80934, or abasales@abasales.com.

Butterflies as Indicators of Restoration Progress gives useful background information on why butterflies are considered wildlife indicators, how restoration treatments affect butterflies, and how to monitor them. The publication also lists useful field guides and website for butterfly identification and butterfly counts. The Working Paper is part of a series produced by the Ecological Restoration Institute at Northern Arizona University. You can obtain a copy of the paper online at www.eri.nau.edu or calling 928-523-7182.

Bosque and Riparian Resources

The **Bosque Education Guide**, second edition, edited by Letitia Morris, Mary Stuever, Lisa Ellis, and Rebecca Tydings, 2003, is an extensive curriculum and resource about the Middle Rio Grande Bosque system and would be useful for education along other parts of the bosque as well. It is produced by Friends of the Rio Grande Nature Center, 2901 Candelaria Road NW, Albuquerque, NM 87107, (505) 344-7240.

The **Rio Grande Nature Center State Park** also produces "traveling trunks" with materials on birds, mammals, arthropods, reptiles and amphibians, bosque models, cottonwoods, botany, bat resources, and geology of Albuquerque. To reserve a trunk, contact the Nature Center at least 2 weeks in advance. Call (505) 344-7240 or write the Rio Grande Nature Center State Park, 2901 Candelaria NW, Albuquerque NM 87107.

Streamkeeper's Field Guide, by Tom Murdoch and Martha Cheo with Kate O'Laughlin, is published by The Adopt-A-Stream Foundation, 600 128th Street SE, Everett, WA 98208, (206) 316-8592. This book provides excellent background on streams and watersheds, with many investigations appropriate for field study.

The **New Mexico Environment Department** compiled a list of groups involved in some aspect of watershed restoration or monitoring throughout the state. A description of each group's work, the watersheds they encompass, and contact information can be found at:
http://www.nmenv.state.nm.us/swqb/wow_grp.html

New Mexico Department of Game and Fish sponsors a program called "Watershed Watch" which provides watershed education for middle and high school students and training in easy-to-follow watershed monitoring and mapping techniques. For information you can contact: Bill Fleming, 901 Trail Cross, Santa Fe, NM 87505; or Rich Schrader, 1803 Agua Fria, Santa Fe, NM 87501.

The **Environmental Protection Agency** provides an interactive website for students and teachers to "surf your watershed" at http://www.epa.gov/surf/. This is a very comprehensive website and provides information for 84 watersheds in New Mexico.

The **U.S. Geological Survey's New Mexico District Office** is located in Albuquerque and can provide information on water resources and geology of New Mexico. To contact, write/call at: USGS New Mexico District Office, 5338 Montgomery NE Suite 400, Albuquerque, New Mexico 87109, (505) 830-7900. Or visit their website at http://nm.water.usgs.gov/ for information specific to New Mexico, or http://usgs.gov/ for general information.

Fire Ecology Resources

Fireworks Curriculum, Featuring Ponderosa, Lodgepole, and Whitebark Pine Forests, by Jane Kapler Smith and Nancy E. McMurray, is produced by the USDA Forest Service, Rocky Mountain Research Station. The curriculum provides many activities in western fire ecology and is on-line at http://www.fs.fed.us/rm/pubs/rmrs_gtr65.html. In addition, there is an internet site (www.firelab.org) which lists locations of Fireworks workshops and trunks on loan. To obtain a CD with posters, booklets, and handouts, contact one of the authors at jsmith09@fs.fed.us or nmcmurray@fs.fed.us.

The Changing Forest: Forest Ecology is a video from the Temperate Forest Foundation that explores the role of fire in a forest ecosystem. Videos are available for $15 for 1-4 orders from the Temperate Forest Foundation, 503-579-6762. The National Park Service Fire Management Program Center offers educational resources in fire ecology including lesson plans and fire facts. For more information, visit their website at: www.nps.gov/fire/educational/edu_tea_interagencyfire.html.

The U.S. Geological Service's Land Use History of North America (LUHNA) provides good background information on land use and land changes for much of North America. The website provides historical photos and data for the Southwestern United States, which may be particularly helpful for Activity 1: Determining Reference Conditions. Visit the website at http://biology.usgs.gov/luhna/. The link http://biology.usgs.gov/luhna/chap9.html gives information specific to the Southwest.

Mapping

Free U.S. Geological Survey topographic maps are available at terraserver-usa.com. Aerial photographs are also available at this site.

Glossary

Glossary terms have been adapted from a variety of sources, including FireWorks Curriculum and Handbook 4: Monitoring Ecological Effects of CFRP Projects.

Adaptation: Something about an organism that helps it survive and reproduce; an aspect of its form, function, or behavior that helps it out-compete other organisms.

Adult Tree: For ponderosa pine, trees with a diameter of 5 inches or larger can be considered adult trees. For juniper or pinyon, trees that are taller than 4.5 feet can be considered adult trees.

Aquifer: An area of land that contains water. Most aquifers are below ground, generally flowing through a layer of rock or soil. People can often access water from aquifers through wells.

Alpine meadow: An open area, primarily of grasses and forbs, located in the higher zones of mountains.

Bark: The tissue that covers stems, branches, and roots of a tree or shrub.

Biodiversity. Variety of living organisms. See diversity.

Bosque: A Spanish word for woods. In the Southwest, bosque refers to the cottonwood forests that line the banks of the Rio Grande and other major waterways.

Botanist: A person who studies plants.

Brood parasite: An organism that uses other species to help them reproduce and rear their young.

Cambium: A thin layer of tissue, located between the bark and the central wood of a tree, where all plant growth occurs.

Canopy cover: The area in a forest covered by tree crowns, measured as the percentage of horizontal cover of the ground that the canopy covers.

Cavity: A hole or hollow place, usually used to refer to a hole in a tree that is used by animals for nesting.

Cavity nester: An animal that uses holes in trees for raising young. Common cavity-nesting birds include northern flickers, house wrens, and mountain bluebirds.

Charred fuels: Fuel that is partly burnt. Usually part of the fuel is blackened.

Combustion: The process of burning, which requires fuel, oxygen, and heat.

Community (Ecological): All of the living organisms that occupy and influence a certain habitat.

Community (Sociological): All the people who reside in one physical area, or who share the same ideas and interests across physical space.

Competition: When two or more organisms seek an environmental resource that may be in short supply.

Composition: A list of all the species that live in an area.

Cone: The physical structure that stores seeds of coniferous plants.

Contour lines: Lines on a topographic map that represent areas that have the same elevation.

Cover: The amount of the ground that is shaded by standing, living understory plants, usually expressed as a percentage. Also, the cover of the ground by dead plants and plant parts, usually called litter.

Crown: The uppermost leafy portion of a tree.

Crown fire: A fire that burns in the canopy of trees. Crown fires can begin as surface fires and then move into the tops, or "crowns," of trees. Then they move rapidly from one crown to another, especially if the wind is strong. During a crown fire, the wind sometimes carries burning branches far ahead of the fire. These "firebrands" can start new fires. A spotting fire "leapfrogs" through the forest, so it can move very fast, especially when it is windy.

Data: A set of observations collected through measurements. The word "data" is plural. The singular form of data is "datum."

Degraded: Reduced quality or condition.

Delineation: Marking the outline of something by drawing lines.

Dendrochronology: The science of learning about trees and climate from tree growth rings.

Density: The number of plants or animals in a given area. For example, tree density is often measured in trees per acre.

Diversity: Variety, for example, of organisms, species, genes, habitats, ecosystems, etc.

Drought: A prolonged period with much lower rainfall than is typical of a region.

Ecologist: A person who studies the relationships between organisms and their environments.

Ecosystem: An interacting system of living plants and animals and the nonliving parts of their environment.

Endangered: Species that are close to extinction. Generally, a classification of a species that is more serious than threatened.

Erosion: The movement or wearing of soil or rocks by wind or water.

Ethnobotany: The study of plants and the ways they are used and managed by people.

Exotic plants: Plants that are non-native to a particular ecosystem or community, that often thrive on disturbed conditions and can become abundant after thinning or burning. Exotic plants can displace and reduce populations of native species.

Extinct: When a species no longer exists, either locally or entirely.

Factors: Specific events, situations, conditions, policies, attitudes, beliefs, or behaviors that may affect the desired future condition.

Field site: The location of a study or project.

Fire intensity: A reference to the amount of heat a fire generates in a particular location and time.

Fire manager: A person who takes actions to prescribe, suppress, or manage wildfires for particular purposes.

Fire regime: The pattern of fire occurrence, size, and severity typical of an ecosystem.

Fire spread: The rate a fire moves per unit of time.

Fire scar: A wound at the base of a tree caused by heat damage to the cambium.

Fire triangle: The three things necessary for fire: fuel, oxygen, and a source of heat.

Flammability: The ease with which a substance will light on fire.

Flooding regime: The pattern of flood occurrence and severity typical of an ecosystem.

Forb: A broad-leafed green plant whose stems are not woody, but not including grasses, sedges, or rushes.

Forest edges: The sides of a forest that intersect with a new ecosystem or environment. Edges may be either naturally occurring or caused by humans. Human caused edges include roads cut through forests, or boundaries set for a forest treatment. However, the use of historical evidence helps create edges similar to those that existed in the past.

Forester: A person who studies forests and is involved in forest management and use.

Fuel: The living and dead vegetation that can be burned in a forest fire. Fuel can include dead woody material from logs and branches, leaves of trees and shrubs, pine needles, grasses, and other plants.

Fuel moisture: The amount of moisture in fuels, expressed as a percent of dry weight. Fuel moisture influences flammability.

Germinate: This term comes from the Latin, germinare, which means "to sprout." Seeds germinate when they begin to grow. Initial signs of germination include the production of a stem with one or two "seed leaves" called cotyledons.

Goal: A general summary of the desired state that a project is working to achieve. A good goal meets the criteria of being visionary, relatively general, brief, and measurable. A goal is typically less specific than an objective.

Ground cover: The cover that grasses, forbs, and other plants cast on the forest floor. Ground cover also includes other materials on the ground, such as needles, leaf litter, and rocks. Ground cover is usually expressed as a percentage.

Ground fire: After a surface fire burns through an area, patches of deep fuel may continue smoldering. This is called a ground fire. Ground fires burn the fallen leaves and small branches that have started to decay and become part of the soil. Ground fires don't move very fast and hardly make any flames. They can take days or even weeks to burn themselves out.

Growth ring: The annual layer of growth in a tree. Also referred to as a tree ring.

Habitat: The place where an organism is usually found and includes food, water, shelter, and nesting conditions that the organism needs to survive.

Heartwood: The central woody core of a tree trunk. Heartwood provides structural support to the tree. It is made of dead xylem cells.

Heat: A form of energy that raises the temperature of matter.

Host: An organism that supports a parasite in some part of its life cycle.

Hypothesis. An informed prediction of the outcome of an experiment. An explanation that can be tested.

Ignition: The act of starting a fire.

Indicator. A unit of information measured over time that documents changes in a specific condition. A good indicator meets the criteria of being measurable, precise, consistent, and sensitive to change.

Ladder fuels. Live shrubs and small trees, dead and leaning logs, and branches of live trees that fill the space between the forest floor and tree crowns with flammable material. Ladder fuels provide a "ladder" from the forest floor to the tops of trees.

Litter: The top layer of soil comprised of a variety of organic material such as dead needles, twigs, branches, and dead grasses and forbs.

Model: An object made to represent something that exists, or a mathematical model that helps explain hypothetical relationships.

Monitoring: The periodic collection and evaluation of data relative to stated project goals, objectives, and activities.

Mortality: The number of deaths in a given time and place.

Multiparty: Involving members from a variety of backgrounds and perspectives.

Native species: A species of plant or animal that naturally occurs in a place.

Needle: A long, narrow specialized leaf, such as a pine needle.

Objective: A specific statement detailing the desired accomplishments or outcomes of a project. If the project is well conceptualized and well designed, realization of a project's objectives should lead to the fulfillment of the project's goals. A good objective meets the criteria of being impact oriented, measurable, time limited, specific, and practical. Objectives are more specific than goals.

Old-growth forest: Patches of forest where old and large trees are found along with trees of other sizes and ages. A forest that has been undisturbed for a long time.

Overbank flooding: When water spreads out over the river banks and into adjacent riparian areas. This occurs when there is more water in the river than the river channel can hold.

Overgrazing: Grazing, usually by cattle or other domesticated animals, to the extent that plants cannot easily grow and soil is degraded.

Oxygen: One of the most common gases in the Earth's atmosphere. Oxygen is produced through photosynthesis of plants and is used during combustion and respiration.

Pack rat middens: Areas where pack rats store quantities of plant material, seeds, and other items. Remains from these middens can provide clues to forest history when they are carbon-dated.

Parasite: An organism that obtains benefits in some way from another organism (the host), usually by harming the other organism.

Phloem. The outer layer of cells produced by a woody plant's cambium. Phloem cells carry sugars and nutrients from the photosynthetic tissue in leaves to other parts of the plant.

Pitch: Resin that comes from coniferous trees; often used synonymously with sap.

Precipitation: Water from the atmosphere that falls to the earth, usually in the form of rain or snow.

Prescribed fire: A wildland fire that is set by forest managers to meet particular goals.

Prescription: A description of actions to be taken in order to achieve forest management objectives.

Reference conditions: The natural or historical conditions of ecosystems that are being restored.

Regeneration: The processes plants use to maintain and expand their populations over time. Regeneration may be through sexual reproduction or vegetative propagation.

Restoration: The process of returning more natural conditions to ecosystems that have been damaged by human activities.

Riparian community: A group of plant and animal species that are related to or grow along the edges of streams, rivers, and other watercourses, including dry streambeds.

Sampling: Measuring a subset of individuals, households, trees, or other factors in a population.

Sap: Liquid that circulates through a plant's vascular system.

Sapling: A tree that is taller than 4.5 feet and has a diameter of less than 5 inches.

Sapwood: The outer woody part of a tree trunk, which surrounds the dead, woody center (heartwood). Sapwood is another term for xylem, the cells that transport water and nutrients from roots to leaves and branches.

Scat: Feces from animals, such as a bear or coyote.

Seedling: A young tree that has not reached sapling size.

Size class: A category for organizing trees into classes of seedlings, saplings, and adult trees.

Slash: Debris, such as branches and needles, that remains on the ground after a thinning.

Slope: The steepness of a hillside.

Snag: A dead, standing tree. Snags provide important habitat for birds, small animals, insects, and fungi. Living snags, where only part of the tree is dead, also provided habitat and may have been the dominant source of snag habitat in a frequent-fire forest.

Soil compaction: Soil that is compressed. When soil is compacted it generally loses its porosity, making it difficult for gases to move, water to spread, and plants to grow.

Soil moisture: The amount of water held in soil pores.

Soil resources: All the components and functions of soil, including the minerals and nutrients of soil, the organisms that live in soil, and seed stores.

Species: A particular kind of living thing. Individuals within a species can breed with each other and produce fertile offspring under natural conditions.

Spot fire: A fire that starts when burning material is carried from an existing fire to a new location.

Stand: A group of trees that can be distinguished as a unit by arrangement of ages, species composition, site quality, or other factors. Forest stands are often used to distinguish an area that will be managed under a set prescription.

Structure: The spatial arrangement (both vertically and horizontally) of parts of an ecosystem.

Surface area: The total area covering the outside (surfaces) of an object.

Surface fire: Fires that burn along the forest floor. Surface fires burn fallen leaves and branches, and wildflowers and grasses on the forest floor. Surface fires also burn bushes and small trees, but they do not burn the tops of grown trees. Surface fires kill a tree only when they are hot enough to damage the roots or kill the growing cells under the tree's bark.

Thinning: The process of cutting some, but not all, trees in an area. The removal of trees (usually small diameter) from a forested area according to a set prescription.

Threatened: A species with an uncertain chance of survival. Generally, a category considered less "serious" than endangered because there are more individuals from a threatened species that live in the wild (than individuals of endangered species).

Topographic map: A map that shows the natural features of a landscape, such as changes in elevation.

Transect: An area, usually along a straight line, that is used for sampling and measurements.

Treatment: The actions to achieve forest management objectives, usually according to a prescription.

Tree cookie: A cross-section cutting of a tree, showing all growth rings and the inner pith.

Tree ring: The annual layer of growth in a tree. Also referred to as a growth ring.

Understory: Plants that grow close to the ground in a forest. These include grasses, forbs, and woody shrubs.

Volatile: Substances that evaporate readily at room temperature.

Volume: The amount of space an object occupies.

Watershed: An area that encompasses all drainages and catchments, bounded by ridges that separate water flowing into rivers and basins from other water flows. The term watershed is also used to refer generally to "drainage basins," which can be smaller or "sub" watersheds.

Water table: The layer of soil that is completely saturated with soil, usually some feet beneath the soil surface.

Wildlife: Animals which are not tamed or domesticated.

Wildlife indicators: Animal species, such as birds and butterflies, that can help show changes in an ecosystem.

Xylem: The inner layer of cells, produced by a woody plant's cambium. Xylem is also called sapwood, and transports water and nutrients from roots to leaves and branches.

Links to Education Standards

The activities in this curriculum can be linked to many national and state standards for science learning. Applicable National Science Education Standards are listed in the table below. In addition, applicable state standards are listed for each activity in subsequent tables. You may want to review these standards in advance so that appropriate concepts are addressed during your lesson.

National Science Education Standards

	Grades 5-8	Grades 9-12
Science as Inquiry	Abilities necessary to do scientific inquiry Understanding about scientific inquiry	Abilities necessary to do scientific inquiry Understanding about scientific inquiry
Physical science	Properties and changes of properties in matter Transfer of energy	Structure and properties of matter Interactions of energy and matter
Life Science	Structure and function in living systems Regulation and behavior Population and ecosystems Diversity and adaptations of organisms	Interdependence of organisms Behavior of organisms Matter, energy, and organization of living systems
Science and Technology	Understanding about science and technology	Understanding about science and technology
Science in Personal and Social Perspectives	Populations, resources, environments Natural hazards Risks and benefits Science and technology in society	Natural resources Environmental quality Natural and human-induced hazards Science and technology in local, national, and global challenges
History and Nature of Science Standards	Science as a human endeavor	Science as a human endeavor Nature of scientific knowledge

New Mexico Science Content Standards, Benchmarks, and Performance Standards for Grades 5-8 that link to Monitoring Curriculum Activities

Strand I: Scientific Thinking & Practice

Standard I: Understand the processes of scientific investigations and use inquiry and scientific ways of observing, experimenting, predicting, and validating to think critically

Benchmark	Activities
5-8 Benchmark I: Use scientific methods to develop questions, design and conduct experiments using appropriate technologies, analyze and evaluate results, make predictions, and communicate findings	1, 3, 4, 5, 7, 8, 10, 11, 12, 13
5-8 Benchmark II: Understand the processes of scientific investigation and how scientific inquiry results in scientific knowledge	1, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
5-8 Benchmark III: Use mathematical tools and techniques to understand scientific knowledge	7, 8, 10, 13

Strand II: Content of Science

Standard II (Life Science): Understand the properties, structures, and processes of living things and the interdependence of living things and their environments

5-8 Benchmark 1. Explain the diverse structures and functions of living things and the complex relationships between living things and their environments

Performance Standard	Activities
Grade 5.3. Know that changes in the environment can have different effects on different organisms	1, 2, 5, 6, 7, 8, 9 10, 11, 12, 13
Grade 5.4. Describe how human activity impacts the environment	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
Grade 6.2. Describe how weather and geologic events affect the function of living systems	2, 3, 4, 5, 6, 7, 12
Grade 6.3 Describe how organisms have adapted to various environmental conditions	2, 5, 6, 7, 11, 13
Grade 7.3. Explain how individuals of species that exist together interact with their environment to create an ecosystem	2, 6, 8, 9, 11, 13
Grade 7.4. Explain the conditions and resources needed to sustain life in specific ecosystems	2, 6, 7, 9, 12, 13
Grade 7.5 Describe how the availability of resources and physical factors limit growth	2, 5, 6, 7, 8, 10, 12, 13
Grade 7.6 Understand how diverse species fill all niches of an ecosystem	2, 6, 7, 9, 10, 11, 12, 13
Grade 8.3. Explain how a change in the flow of energy can impact an ecosystem	2, 3, 4, 7, 12, 13

New Mexico Science Content Standards, Benchmarks, and Performance Standards for Grades 5-8 that link to Monitoring Curriculum Activities (continued)

Strand II: Content of Science

Standard II (Life Science): Understand the properties, structures, and processes of living things and the interdependence of living things and their environments

5-8 Benchmark II: Understand how traits are passed from one generation to the next and how species evolve

Performance Standards	Activities
Grade 6.2. Describe how species have responded to changing environmental conditions over time	1, 2, 5, 6, 7, 11, 12
Grade 7.10. Identify adaptations that favor the survival of organisms in their environments	2, 4, 6, 7, 11, 12
Grade 7.12. Explain how species adapt to changes in the environment or become extinct and that extinction of species is common in the history of living things	2, 6, 7, 12

Strand II: Content of Science

Standard II (Life Science): Understand the properties, structures, and processes of living things and the interdependence of living things and their environments

5-8 Benchmark III Understand the structure of organisms and the function of cells in living systems

Performance Standards	Activities
Grade 7.3. Understand that many basic functions of organisms are carried out in cells, including specialized functions of cells	5

Strand II: Content of Science

Standard III (Earth and Space Science): Understand the structure of Earth, the solar system, and the universe, the interconnections among them, and the processes and interactions of Earth's systems

5-8 Benchmark II: Describe the structure of Earth and its atmosphere and explain how energy, matter, and forces shape Earth's systems

Performance Standards	Activities
Grade 7.1. Understand how the remains of living things give us information about the history of Earth	1, 5, 6
Grade 7.2. Understand how living organisms have played many roles in changes of Earth's systems through time	1, 2, 6, 13
Grade 7.3. Know that changes to ecosystems sometimes decrease the capacity of the environment to support some life forms and are difficult and/or costly to remediate	2, 5, 6, 7, 9, 10, 11, 12, 13

New Mexico Science Content Standards, Benchmarks, and Performance Standards for Grades 5-8 that link to Monitoring Curriculum Activities (continued)

Strand III: Science and Society

Standard I: Understand how scientific discoveries, inventions, practices, and knowledge influence and are influenced by, individuals and societies

5-8 Benchmark I: Explain how scientific discoveries and inventions have changed individuals and societies

Performance Standards	Activities
Grade 5.1. Describe the contributions of science to understanding local or current issues	1, 5, 13
Grade 6.1. Examine the role of scientific knowledge in decisions	5, 8
Grade 8.2. Describe how scientific information can help to explain environmental phenomena	1, 3, 5, 9, 12, 13
Grade 8.3. Describe how technological revolutions have significantly influenced societies	2, 7, 10, 12, 13

New Mexico Science Content Standards, Benchmarks, and Performance Standards for Grades 9-12 that link to Monitoring Curriculum Activities

Strand I: Scientific Thinking & Practice

Standard I: Understand the processes of scientific investigations and use inquiry and scientific ways of observing, experimenting, predicting, and validating to think critically

9-12 Benchmark II: Understand that scientific processes produce scientific knowledge that is continually evaluated, validated, revised, or rejected.

Performance Standards	Activities
1. Understand how scientific processes produce valid, reliable results	1, 3, 4, 5, 7, 8, 10, 12, 13
2. Use scientific reasoning and valid logic to recognize faulty logic, cause and effect, difference between observation and unsubstantiated inferences, potential bias	1, 2, 3, 4, 5, 7, 8,
3. Understand how new data and observations can result in new scientific knowledge	1, 5, 8, 10, 11, 13
5. Examine investigations of current interest in science	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
6. Examine the scientific processes and logic used in investigations of past events	1, 5, 6

Strand I: Scientific Thinking & Practice

Standard I: Understand the processes of scientific investigations and use inquiry and scientific ways of observing, experimenting, predicting, and validating to think critically

9-12 Benchmark III: Use mathematical concepts, principles, and expressions to analyze data, develop models, understand patterns and relationships, evaluate findings, and draw conclusions

Performance Standards	Activities
3. Use technologies to quantify relationships in scientific hypotheses (e.g., calculators, spreadsheets)	7, 8, 10, 11,13
4. Identify and apply measurement techniques and consider possible effects of measurement errors	5, 7, 8, 10, 11, 12, 13
5. Use mathematics to express and establish scientific relationships	7, 8, 10, 13

New Mexico Science Content Standards, Benchmarks, and Performance Standards for Grades 9-12 that link to Monitoring Curriculum Activities (continued)

Strand II: The Content of Science

Standard I (Physical Science): Understand the structure and properties of matter, the characteristics of energy, and the interactions between matter and energy

9-12 Benchmark I: Understand the properties, underlying structure, and reactions of matter

Performance Standards	Activities
15. Describe how the rate of chemical reactions depends on many factors that include temperature, concentration, and the presence of catalysts	2, 3, 4

Strand II: The Content of Science

Standard II (Life Science): Understand the properties, structures, and processes of living things and the interdependence of living things and their environments

9-12 Benchmark I: Understand how the survival of species depends on biodiversity and on complex interactions, including the handling of matter and the flow of energy

Performance Standards: Ecosystems	Activities
1. Know that an ecosystem is complex and may exhibit fluctuations around a steady state or may evolve over time.	1, 2, 5, 7, 8, 11, 12, 13
2. Describe how organisms cooperate and compete in ecosystems	8, 9, 11, 13
3. Understand and describe how available resource limit the amount of life an ecosystem can support (e.g., energy, water, oxygen, nutrients)	2, 5, 6, 7, 8, 10, 12, 13
4. Critically analyze how humans modify and change ecosystems	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13

Performance Standards: Biodiversity	Activities
8. Understand and explain the hierarchical classification scheme including: classification of an organism into a category, similarities of organisms reflecting evolutionary relationships	7, 13
9. Understand variation within and among species, including factors that affect the survival of an organism	1, 2, 4, 5, 6, 7, 11, 12

New Mexico Science Content Standards, Benchmarks, and Performance Standards for Grades 9-12 that link to Monitoring Curriculum Activities (continued)

Strand II: The Content of Science

Standard III (Earth and Space Science): Understand the structure of the Earth, the solar system, the universe, the interconnections among them, and the processes and interactions of the Earth's systems

9-12 Benchmark II: Examine the scientific theories of the origin, structure, energy, and evolution of Earth and its atmosphere, and their interconnections

Performance Standards	Activities
9. Know that Earth's system contains a fixed amount of natural resources that cycle among land, water, the atmosphere, and living things (e.g., carbon and nitrogen cycles, rock cycle, water cycle, ground water, aquifers)	13

Strand III: Science and Society

Standard I: Understand how scientific discoveries, inventions, practices, and knowledge are influenced by individuals and societies

9-12 Benchmark I: Examine and analyze how scientific discoveries and their applications affect the world, and explain how societies influence scientific investigations and applications

Performance Standards	Activities
3. Evaluate the influences of technology on society	2, 7, 10, 12, 13
9. Describe how scientific knowledge helps decision makers with local, national, and global challenges	1
11. Know that societal factors can promote or constrain scientific discovery (e.g., government funding)	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
12. Explain how societies can change ecosystems and how these changes can be reversible or irreversible	1, 2, 5, 6, 7, 10, 11, 12, 13
13. Describe how environmental, economic, and political interests impact resource management and use in New Mexico	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13