kNOweeds

K-12 Montana Invasive Plant Curriculum Guide

MISSOULA COUNTY
WEED DISTRICT

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For an online version of the Guide and
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Introduction

Almost anyone who has spent time outdoors in Montana has been affected by non-native, invasive plants (often referred to as “weeds”). Whether it is seeing knapweed replacing native wildflowers in your favorite family camping spot, struggling to keep leafy spurge from taking over livestock range, or keeping thistles out of crop lands, invasive plants impact Montanans. And humans aren’t the only inhabitants affected; invasions in natural areas can result in losses of native plants and cause changes in the fauna that depend on them.

Plant and animal species are introduced, purposefully or unintentionally, from all over the world. While only about 1% of introduced organisms become invasive—that is, grow and spread rapidly in their new environment—those relatively few invasive species can have enormous impacts. Invasive plants are highly successful organisms that are very good at their evolutionary jobs of survival and reproduction. These traits, while admirable in the abstract, cause significant problems in some cases. Some species can be difficult or impossible to control where they invade. Controlling them costs ranchers, farmers, conservation groups, utility companies, governments, and citizens millions of dollars each year. For example, in Montana alone, spotted knapweed is estimated to cost $42 million each year (Montana’s Statewide Noxious Weed Awareness and Education Program, 2005).

The complexity of managing invasive plants is a reflection of the complexity of ecology and the various priorities of the people involved. For example, priorities and objectives for controlling invasive plants in a park may be very different than those on agricultural land. Issues of expense, effort, safety, effectiveness, and unintended consequences must be considered, and research on invasive plants is an important component of their management.

Education about invasive species, their effects, and their management is essential for many reasons. Human actions can have a tremendous impact on the spread of invasive species in many ways. Awareness of the issues surrounding invasive plants and their management can help prevent their introduction into new places and encourage individual and group efforts to restore desirable plant communities. Even as youth, students can have both direct and indirect effects on invasive species management, and so education at the school level is very important. The students of today will become adults of tomorrow, potentially participating in important decisions related to invasive plants in their communities, and this background knowledge will provide a basis from which they can build a deeper understanding of the issues. Although there are many invasive plant curricula available throughout the U.S., most of these are geographically inappropriate for Montana or limited in the types of land use or management they cover. It was felt that the need exists for a comprehensive,

Purple Loosestrife
Lythrum salicaria

place-based, and scientifically accurate curriculum that promotes effective, inquiry-based teaching about invasive plants in all the diverse landscapes of Montana.

The **kNOweeds: K-12 Montana Invasive Plant Curriculum Guide** provides such a place-based, ecologically accurate curriculum for Montana K-12 schools. The curriculum was designed as a supplementary resource for teachers who want to integrate the topic of invasive plant species into their existing courses. Instructors can select lessons from a wide range of topics based on their specific needs and grade level(s). The primary audiences of this curriculum guide are teachers of kindergarten through high school level students. However, many lessons are also appropriate for educators in non-school settings, such as resource professionals whose work includes teaching about invasive plants in Montana.

The **kNOweeds Guide** incorporates a variety of learning styles at all levels and draws on a wide range of subject areas across the curriculum. However, there is an emphasis on encouraging scientific inquiry, where students use observation, data collection, and deductive reasoning to develop their own answers. Some lessons use a very guided approach to student inquiry, while others are more open-ended and allow students to develop their own methods of investigation.

The Guide contains place-based lessons that encourage student inquiry and reflect the diversity of land values and users throughout the state. A conceptual framework was developed to ensure ecological comprehension and pedagogical correctness. Lessons are linked to national and state curriculum standards, and external piloting and field testing of the guide by Montana educators ensure its usefulness in both formal and informal educational settings.

The Guide will provide educators with a curriculum that helps students learn about important concepts in basic ecology as well as develop the awareness, knowledge, and skills for responsible land stewardship in Montana.

Using the **kNOweeds** Curriculum Guide

The **kNOweeds** Guide is designed to address curricular needs of students in kindergarten through high school. It consists of 46 lessons, some designed primarily for use with primary students (grades K-8) and some for secondary students (9-12). Most lessons are intended to apply to a short range of grade levels, such as grades 3-5. However, many lessons can be extended up or down grades with some adaptation by teachers. Each lesson was planned to meet state and national science standards, cover key concepts related to invasive plant education, and be grade-level appropriate.

USE OF INQUIRY

We have attempted to incorporate scientific inquiry into lessons as much as possible. By this, we mean providing teachers and students with the opportunity and guidance to actively engage in the process of science: making observations, devising questions, recording and summarizing information, coming to conclusions, and communicating with others about their discoveries. Some lessons incorporate many or all of these elements, while others use a few or less. Some lessons rely heavily on teachers guiding students in their learning, and others allow for more open-ended exploration. We encourage teachers to adapt lessons to the level of inquiry with which they are comfortable.

Important skills in science include making **observations** and making **inferences**. Students often confuse observation and inference, so it is important to help them learn to make a distinction between the two. When we describe something based on our five senses, it is called an observation. For example, "There are 20 plants in our plot that are over 10 inches tall and have purple flowers." Observations are direct or "objective" enough that most people would make the same observation if faced with the same situation again.

When we make interpretations or judgments about something based on our past experiences, we are making inferences. "These plants are invading our schoolyard" is an inference. Inferences generally use knowledge outside of what is directly observed at the moment, and involve cause-and-effect relationships. Inferences are important in making scientific explanations, but we must be careful not to confuse observations with inferences in a study. For more on inquiry and science skills see the **Resource** section of this guide.

CONCEPTS

Lesson development was based on a conceptual framework (see page 21) of topics thought to be necessary to develop a thorough understanding of invasive plants and the issues around them. Each lesson addresses one or more of these concepts and ***Lesson Index 1: Concepts, Objectives and Descriptions*** shows this relationship. The concepts covered fall into three broad categories:

BUILDING BASICS (plant uses and basic biology), **INTRODUCING INVASIVES** (invasive species biology and impacts), and **TAKING ACTION AND LENDING A HAND** (invasive plant management and turning knowledge into action).

There are lessons for all grade levels that cover some of the concepts within each of these three areas. However, generally the more basic concepts in a category are approached in lessons for younger students and more complex concepts are covered at the higher grade levels. For example, differences in the growth rates of plant species are found in lessons for K-4 students, while students in upper primary grades will learn how interspecific competition can affect plant growth, and high school students can study allelopathy as a mechanism for competition.

STANDARDS

Most teachers have a great number of topics they must cover within the school year in order to meet national, state and local curriculum standards, improve standardized test scores, and satisfy their local school community. Therefore, every effort has been made to develop lessons aligned to the standards and incorporate or reinforce basic science concepts expected to be covered in standardized tests. We hope this curriculum will enhance the lessons teachers must already address. You can use ***Lesson Index 2: Science Standards and Subject Areas*** to determine standards addressed in each lesson.

OUTDOOR LEARNING

Many lessons incorporate a field element. Given the constraints most schools face of minimal time and financial resources available for field trips, we have designed most lessons so that "field work" can be done in the schoolyard, a neighborhood park, an empty lot, playing field, or another easily accessed site. School grounds can be excellent resources for all kinds of scientific studies and inspired learning; for more on this topic, see the Resource Section of this Guide. If you have never taken students into the schoolyard for science, be sure to start with a simple, manageable lesson, such as ***Lesson 27: Schoolyard Plant Safari***.

If you are worried about keeping order outside the classroom, discuss with your students beforehand how they will need to behave to create a good learning environment. Remind them that they are still having a school lesson, even if they are not in the classroom. Try to recruit some help from parents or older students. Keep your lesson short and focused, but also allow students the opportunity to observe on their own, keeping in mind that learning is happening if they are noticing things about the world in their schoolyard. Your students are not likely to work as quietly as mice when they are outside, especially during cooperative group activities. Noise does not necessarily mean they are not learning! See the Resources section of this Guide for more on outdoor learning.

SAFETY

Before you take your students outside, be sure to explain to them that some things in nature, just as in their house, can be dangerous and should be treated with caution. **THEY SHOULD NEVER TASTE ANYTHING THEY FIND.** Plants and animals should be handled very carefully. Plants may have thorns or toxic substances that can cause skin irritations. Any animal may bite, and invertebrates such as bees, wasps, centipedes, and some spiders may cause a potentially dangerous reaction in some people.

Students should be made aware of the physical boundaries of where they are allowed to go before you go outside. Losing fieldwork privileges may provide an effective motivation for staying within those boundaries!

EFFICIENCY

Efficient use of time will greatly improve your chances of finishing lessons outdoors and providing a good learning experience for your students. To make your time outside more efficient, make it clear to your students that you are going outside to learn, not for recess. If they have clear directions at the beginning of the lesson about what tasks they are responsible for accomplishing and how much time they have to do them, they are more likely to stay on task. Having a device on hand to get their attention when you need to tell them something or move on will help keep the class on schedule (bird calls, whistles work well).

ETHICS

Explain to your students that they are expected to behave respectfully toward the organisms and environments they are going to study. You may want to begin by asking them how they expect a guest in their house to behave. After they have given replies, then ask if they know whose homes they will be in as they conduct their fieldwork. How do the rules for good guests apply to where they will be working? The results of their research as well as ethical reasons dictate that they not kill organisms or remove them from their homes, break branches or tear off leaves, chase animals or throw things at them, or collect plants or even parts of them unless specifically told by you that they may (only for very specific needs, when other methods will not suffice). As with much of what you teach them, modeling careful treatment of the natural world and interest in how it works will be your most powerful technique.

Any collecting of natural materials should not cause any significant change in the environment of the site (unless it is removal of invasive plants!). When possible, collect parts of plants instead of the whole plant, and use drawings, descriptions, or photos in place of collecting. Have your students come up with a list of their own rules to use related to outdoor learning. You may want to prompt them to think about personal safety, laws, land ownership, and environmental ethics.

Canada Thistle
Cirsium arvense

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STUDENT JOURNALS

Have each student keep a field journal for all their outdoor projects. ***Lesson 4: Making a kNOweeds Journal*** is a good one to do prior to any field activities. Journals can be used for writing observations, ideas, and questions; sketching; jotting down instructions for projects; recording data; outlining reports, etc.

MOTIVATION

Your students may be more motivated to participate in ecological investigations if they have some outside interest in their projects: for example, a local biologist who wants their information; another school or class with whom to share and compare information; a chance to present their findings to a community group, etc. They also may be motivated if they can apply their knowledge to solving a problem: what the school should do with an empty portion of the schoolyard; how to improve their schoolyard habitat for wildlife; or what impact a particular action may have on the biodiversity of their area.

PRACTICING OBSERVATIONS AND DESCRIPTIONS

Before you have your students begin actually collecting information outside, have them spend some time practicing their skills at observation and description (two very important and basic tools used by most scientists) in the classroom.

Practice observing and describing familiar objects before you go outside, so that students are already aware of what they will be expected to do. Some simple hand lenses are good tools for practice as well as outdoor lessons.

Collect some small natural objects from your area, such as rocks, pine cones, and small tree branches. Pass around an object for them to examine. As students examine the object, ask them for words which describe the object. Encourage them to give descriptions based on senses other than just sight. (**Do not* allow them to taste any non-food objects, and explain to them that they should never use their sense of taste on things other than food, since it is dangerous to taste objects not known to be safe to eat.) You may want to write their descriptions on the board under headings for each of the senses: See—Touch—Hear—Smell.

Next, for younger students (K-2), have them draw a picture of an object in the room. Ask them to label or describe parts of the object to give more detail or explanation. Ask them to share their drawings with another student.

If you are working with older students, give each student or pair of students an object. Have them write a description in their journal of the object. Tell them to be as careful and detailed as possible – as if they were describing a suspect or missing person to a detective.

After a few minutes, give each student a hand lens and show them how to use it. Now have them observe their object again, this time with the lens, and note any additional observations they make. When they are finished, collect the objects, mix them up, and pass them out to different students. Have students read their descriptions aloud. When a student thinks they are holding the object being described, they should raise their hand. Can the student who described it recognize it? This can be a fun test of both their power of observation and their descriptive abilities.

Ask students if they observed anything using the hand lens that they hadn't noticed without it. Do they see hand lenses as helpful tools for outdoor research? Can they think of other tools that might improve their observations?

HOW TO USE THIS GUIDE

This guide contains reference indices which list each lesson and the topics and concepts it addresses, grade levels, and science standards covered. ***Lesson Index 1: Concepts, Objectives and Descriptions*** is a matrix which shows the title of each lesson, its targeted grade-levels, concepts addressed by the lesson, objectives of the lesson, and a brief description of the lesson activities. ***Lesson Index 2: Science Standards and Subject Areas*** shows the grades targeted for each lesson, the National and Montana Science Standards met by teaching the lesson, and other (non-science) subject areas addressed.

LESSON FORMAT

Each lesson in this guide is formatted in the same way. The lesson has the following sections:

Objectives: A statement of what students should learn from this lesson.
Method: A brief description of the activities in the lesson.
Materials: A list of everything needed to complete the lesson.
Background: Facts about the specific subject of the lesson to help the instructor better understand the concepts.
Procedure: A step-by-step explanation of how to do the lesson activities.
Extensions: Additional activities to extend the learning about this subject.

Each lesson also has sidebar information on its first page (see example at right) that allows the instructor to quickly gather practical information about the lesson.

Quick lesson reference example

Grade level: K-4
Subject Areas: Biology, language arts, literature
Duration: 30-45 minutes
Setting: Classroom
Season: Any
Conceptual Framework Topics: Life cycles, habitats

kNOweeds Lesson Index 1

BUILDING BASICS: Constructing Knowledge About Plant Uses and Plant Biology

Lesson *Page*	**Title**	**Concepts Addressed**	**Targeted Grade Levels**	**Objectives**	**Description**
1 *p. 31*	**Discovering Plants Through Observing and Reading**	plant life cycles, habitat	K-4	Student will be able to identify needs and characteristics of plants and understand how they commonly reproduce.	Students share their collective knowledge about plant biology while examining a real plant, and then together read a story (*The Tiny Seed*) and discuss what they have learned about plants.
2 *p. 33*	**The Seed: It All Starts Here (Well, Almost All)**	life cycles, plant anatomy, growth, reproduction	K-4	Students will understand that most plants start from seeds, but some also start from tubers or bulbs. They will realize that there are many different types of seeds and they will learn to recognize the parts of seeds and their functions.	Students examine different types of seeds and bulbs, figuring out what plants they come from. They observe and dissect lima bean seeds, learning how water affects seeds and identifying the seed parts and their functions.
3 *p. 35*	**Who Needs Plants?**	plant values to people	K-8	Student will be able to name 5-10 everyday objects that are made from or possible by plants.	Students make lists of objects in the classroom that are made (directly or indirectly) from plants. They take home a sheet on which to record their dinner and what parts of it come from plants, or they can do this step with their lunch.
4 *p. 39*	**Making a kNOweeds Journal**	plants provide products of economic value	K-8	Students know the importance of wood products to people and the process of how paper is made as they make their own kNOweeds Journal. Students are able to use the journal as a tool for scientific journaling.	Students discuss the importance of wood products in their lives, and create a field journal for use on class field studies or on their own.
5 *p. 45*	**Montana's Native People and Plants**	aesthetic, recreational and spiritual values of plants, species, habitat, weed management	K-4	Students will understand the importance of many plant species to Montana's early people. They will be able to identify uses for at least 2 different species of plants.	Students read a Salish legend in which Montana's state plant, the bitterroot, played a vital part in survival of early people. They research use of plants and learn how other plants were and are used by Montana's native people.
6 *p. 53*	**The Story of the Bitterroot**	aesthetic, recreational and spiritual values of plants, species, habitat, weed management	5-8	Students will understand the importance of the bitterroot plant to the Salish people of western Montana. They will realize how the plant is interwoven into the culture of the tribe, as well as learning about the plant's biology and the changes that have affected both the plant and the people over the past 150 years.	Students watch a video about the Salish tribe and Montana's state plant, the bitterroot, and their interconnected story. They discuss the film using guided discussion questions, and research how other plants were and are used by Montana's native people.

❋ Denotes lessons appropriate for the high school level ✋ Denotes service learning through hands-on involvement in invasive plant management

BUILDING BASICS: Constructing Knowledge About Plant Uses and Plant Biology

Lesson *Page*	**Title**	**Concepts Addressed**	**Targeted Grade Levels**	**Objectives**	**Description**
7 ❋ *p. 61*	**Traditional Uses of Native Plants**	ethnobotany	K-12	Students will understand that there are many ways in which native plants can be used directly by people today. They will learn at least 2 ways to use native plants themselves. They will consider a variety of topics related to the firsthand use of native plants by people.	Students create a craft project, a medicinal salve, and a food item from common native Montana plants that are safe for human use.
8 *p. 73*	**We Grow Wheat and Eat Tortillas**	importance of Montana agriculture, invasive plant impacts	K-4	Students will understand how Montana's primary agricultural crop grows and is made into flour and used in cooking. They will understand that weeds can threaten the production of important crops like wheat.	Students observe and journal the process of sprouting a kernel of wheat. They grind wheat and make tortillas from the flour they make.
9 ❋ *p. 77*	**Local Color: Dyeing with Plants**	humans and plants, ethnobotany, plant identification	6-12	Students will learn about ethnobotany by exploring ways Native Americans and Europeans utilized plants, practice plant identification skills; and extract and use plant dyes from hand-collected, locally growing material.	Students discuss the importance of plants in historical and modern settings. A hands-on activity helps students to identify, collect, and extract dye from locally growing plants to naturally dye a final product. Select plant identification skills are cemented when students determine and draw the key distinguishing features of their local plant of choice.
10 *p. 83*	**Know Your Neighbors**	species, classification, identification	K-8	Students will learn how to collect and preserve plants, and understand why plants are collected. They will understand how to carefully collect so as not to harm desirable species that are uncommon. Students will learn about native and non-native plants in their area and will be able to identify at least 2 common native plants and 2 common local weeds.	Students visit outdoor sites to examine different species of native plants and non-native, invasive species. They create their own mini weed I.D. booklet by collecting and pressing samples of weed species, writing their own descriptions of what the plant looks like and where it grows, and sketching (or alternatively, for younger students, coloring in) details of it. They put it all together in the classroom after their pressed samples are ready.
11 *p. 89*	**Who Lives Here? Plants as Environments**	organisms and environments, interdependence, populations, habitats, classification, biodiversity	K-8	Students will understand that plants provide habitat for animals. Different types of plants provide living conditions for different animals, which may in turn influence other species living in the same area. Changes in vegetation may have cascading effects on animals living in an area as the components of an ecological web.	Using equipment made with common, easily-obtainable materials, students collect invertebrates living on local plants. They sort and count the different types they find, and compare *assemblages* of invertebrates on different plant species. Students create an ecological web based on their findings and discuss how changes in vegetation due to plant invasions might have cascading effects on an area.

❋ Denotes lessons appropriate for the high school level ✋ Denotes service learning through hands-on involvement in invasive plant management

INTRODUCING INVASIVES: Learning About Invasive Plant Ecology and Impacts

Lesson *Page*	**Title**	**Concepts Addressed**	**Targeted Grade Levels**	**Objectives**	**Description**
12 *p. 93*	**What's in a Name?**	plant ecology, habitats, invasive species	K-8	Students will learn why some plants are considered weeds. They will understand the meanings of the terms weed, native, non-native, invasive, and noxious.	Students examine plants and pictures of plants that illustrate examples of non-native ("out of place") species, some of which are considered weeds, some of which are invasive and noxious. They discuss how these terms are applied to different plant species.
13 ❋ *p. 99*	**A Weed by Any Other Name…**	plant ecology, habitats, invasive species, mechanisms of invasion, Montana invasive species	6-12	Students will understand the meanings of the terms weed, native, non-native, invasive, and noxious. They will learn why invasive plants cause ecological damage and affect humans.	Students watch a slideshow (PowerPoint) that challenges them to consider and discuss examples of non-native ("out of place") species, some of which are considered weeds, some of which are invasive and noxious. They discuss how these terms are applied to different plant species, and how context and perspective influence how and when they are used.
14 *p. 105*	**Noxious or Native?**	plant biology, noxious weeds, invasive species ecology	2-8	Students will be able to identify at least 2 Montana noxious weeds and 2 Montana native plants, and name several characteristics common to all plants.	Students write descriptions of plant for others to read and then identify the plant from a selection of plant photos.
15 *p. 109*	**The Key to Montana Weed I.D.**	species, classification, identification, tools and technology, invasive plants in Montana	4-8	Students will understand what a dichotomous key is and how to use one. They will learn to identify distinguishing characteristics that separate one plant species from another. They will be able to identify 6 of Montana's noxious weeds using a simple key.	Students use a very simple key to "identify" different types of candy. They then use a more sophisticated but easy-to-use key to identify noxious weeds of Montana.
16 ❋ *p. 117*	**We Can't Eat Weeds!**	agriculture, economics of plants, impacts of invasive plants, invasive plant management	5-12	Students will understand the importance of agriculture in Montana and how weeds impact the agricultural industry and the food we all eat.	Students search for food produced in Montana and learn how many different types of agricultural products are grown in the state. They calculate production and economic values of different crops using agricultural statistics data, and use economic thresholds to determine whether to use weed controls at different levels of weed infestations.
17 *p. 127*	**Plant Adaptations**	plant adaptations to environment	K-8	Students will understand that some plants have very specific adaptations that allow them to exploit different environments and survive under a range of conditions. How plants conserve water is one important adaptation that is readily observable.	Students observe different kinds of plants and their leaves and discuss how they are adapted to differing levels of water availability. They compare plant types in varying micro-habitats around the schoolyard or other field site. They then predict traits of successful invasive species and compare their predictions to invasive species in Montana.

❋ Denotes lessons appropriate for the high school level ✋ Denotes service learning through hands-on involvement in invasive plant management

INTRODUCING INVASIVES: Learning About Invasive Plant Ecology and Impacts

Lesson *Page*	**Title**	**Concepts Addressed**	**Targeted Grade Levels**	**Objectives**	**Description**
18 *p. 131*	**Weed Success: A Bag of Tricks**	plant ecology, invasive plant management	5-8	Students will be able to identify life-history strategies that make some plants successful invaders.	Students brainstorm what characteristics of plants might make them successful invaders. They research noxious weed species of Montana and demonstrate traits their species uses to help it successfully invade new areas.
19 *p. 135*	**Measuring the Competition**	species, classification, plant reproduction and growth, competition, invasive plant ecology	K-5	Students will understand how plants grow from seeds. They will be able to measure and record plant growth and know that different species of plants grow at different rates.	Students grow 2 different species of plants from seeds. They measure and record their growth and compare the growth rates of different types of plants, and relate this to weed growth.
20 ❋ *p. 139*	**Investigating Plant Competition**	plant growth, ecological competition, invasive species ecology	6-12	Students will understand that competition for limited resources may affect plant germination and growth. They will understand that this is one detrimental effect of invasive plants on native and crop plants.	Students investigate interspecific plant competition for limited resources by germinating and growing seeds in the presence of varying numbers of other plants.
21 ❋ *p. 145*	**Plant Warfare: Investigating Allelopathy**	plant competition, allelopathy, invasive species ecology	9-12	Students will understand the concept of allelopathy and how it affects plant germination and growth. They will understand how allelopathy helps invasive plants outcompete native plants.	Students experimentally test the effects of plant extracts on seed germination by comparing germination rates of seeds bathed in extract to those in water
22 *p. 149*	**Who Drank All The Water?**	plant water use, competition, impacts of invasive plants	4-8	Students will understand how a noxious weed, salt cedar, uses tremendous amounts of water, affecting other plants and people.	Students estimate how much water a saltcedar tree can use in a day and then use jugs to fill a container representing a fraction of the actual amount. They use different lengths of twine to represent root lengths in saltcedar and native willows, to explore how saltcedar can exploit water sources far beyond the reach of native plants.
23 *p. 153*	**A Grain of Rice and a Hillside of Knapweed**	plant reproduction, invasive species ecology, invasive species spread by seed, plant populations and demographics	4-8	Students will be able to define "noxious weed," understand the awesome power of exponential growth, and be able to apply the concept of exponential growth to knapweed population increase.	As students listen to a folktale that illustrates the importance of understanding exponential growth, they calculate the numbers of grains of rice as they increase in the story. They explore how exponential growth applies to knapweed reproduction and population growth.

❋ Denotes lessons appropriate for the high school level ✋ Denotes service learning through hands-on involvement in invasive plant management

INTRODUCING INVASIVES: Learning About Invasive Plant Ecology and Impacts

Lesson *Page*	**Title**	**Concepts Addressed**	**Targeted Grade Levels**	**Objectives**	**Description**
24 *p. 157*	**Hitching a Ride**	plant reproduction, plant populations and demography, invasion ecology, human factors	K-4	Students will be able to identify common ways that weeds spread by seed.	Students use toy vehicles in a model landscape to examine how seeds can be carried by vehicles, boots, and other means, promoting the spread of undesirable plants to new locations.
25 *p. 159*	**The Knapweed Hitchikers**	seed dispersal, plant invasion in disturbed sites	5-8	Students will be able to predict the spread of spotted knapweed over time based on seed germination rates.	Students calculate the rate of weed spread from a recreational activity presented in a story, and discuss how weeds are spread and the role individuals can play in reducing weed spread.
26 ❋ *p. 163*	**Aquatic Invaders**	integrated weed management, weed control, plant ecology	K-12	Students understand the impact of aquatic invasive plants on ecosystems. Students know how one of Montana's newest aquatic invaders, Eurasian watermilfoil, spreads into new environments and what can be done to help prevent its spread.	Students demonstrate and discuss ways that Eurasian watermilfoil and other aquatic invasive species can be spread inadvertently to new locations during recreational and other activities.
27 *p. 167*	**Schoolyard Plant Safari**	plant identification, data collection, weed invasion	K-8	Students will be able to record basic scientific information in a field journal, and identify and record plant and habitat characteristics.	Students are guided in the use of journals to record scientific discoveries.
28 *p. 169*	**Map Mysteries**	plant identification, weed management, citizen science and service, inventorying and mapping native and invasive plants	2-8	Students will be able to create a map of a local area featuring predominant plant species (both desirable and invasive species).	Students work in teams to create a map including the predominant plant species. Students will learn about the mapping process used by land managers in addressing invasive plant issues.
29 *p. 171*	**Adopt-A-Nature Trail**	species, classification, identification, plant ecology, invasive species	2-8	Students will know how to identify local plants and their status (native or non-native, invasive, etc.) and values. They will become skilled at sharing their knowledge with their community through a nature trail with plant labels and signs.	Students learn about plants in their schoolyard or nearby neighborhood. They research their plant and make simple signs to label plants they identify, with information about the plant, to teach other students or members of their community about local plants, including invasive species.
30 *p. 175*	**Changes on the Land**	weed management, monitoring	2-6	Students will be able to explain the reasons for monitoring a weed-infested site and the importance of monitoring on a long-term basis.	Students conduct a monitoring study of a weed-infested area using hula-hoops to outline their study plots. Students collect data on the distribution of native and invasive plants over time.

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INTRODUCING INVASIVES: Learning About Invasive Plant Ecology and Impacts

Lesson *Page*	**Title**	**Concepts Addressed**	**Targeted Grade Levels**	**Objectives**	**Description**
31 ❋ *p. 181*	**Virtual Survey of Invasive Plants**	plant distributions, habitat, invasive species management, mapping and survey techniques	7-12	Students will be able to understand the difference between a survey and a census, understand and implement different sampling techniques, and recognize that plants (including weeds) grow in specific niches or habitats.	Students develop a weed sampling plan on a map of a park. They check the results of their sampling plan and calculate the area and percent of the park that is invaded by weeds.
32 ❋ *p. 187*	**Weed Detectives: Surveying for Invasive Plants**	plant distributions, habitat, invasive species management, mapping and survey techniques	9-12	Students will understand how and why areas are surveyed to determine whether invasive plant species are present. They will be able to conduct early detection surveys.	Students learn about noxious weed species in their area. They learn how to conduct early detection surveys for those plants. They practice recording data for the surveys on the school grounds before using them in the field to survey for local invasive species.
33 ❋ *p. 193*	**Sampling Invasive Plant Populations**	plant distributions, habitat, invasive species management, plot sampling techniques	9-12	Students will understand why scientists use plot samples to estimate the population size or relative abundances of invasive plants. They will know how to estimate the density and percent cover of invasive species in an area, and how to analyze data they collect and interpret the results.	Students learn about noxious weed species in their area, and devise a comparative question that can be answered by sampling plant populations. They learn how to randomly select plot locations, make inexpensive and simple quadrat frames, and collect data on the density and percent cover of plants within the plots. They analyze and interpret their results.
34 *p. 197*	**Weeds Are an Earthmoving Problem**	plant ecology, impacts of invasive species on ecosystems, weed management, soil disturbance and site recovery	3-5	Students will be able to identify signs of erosion and explain the causes of erosion, how the natural diversity of plants in the landscape can help prevent erosion and how weed invasion can lead to an increase in soil erosion.	Students will observe and record signs of erosion in the schoolyard, demonstrate erosion using a soil tray, and discuss how invasive plants can increase erosion.
35 *p. 201*	**Wildlife Weed Woes**	invasive species, weed management, ecological impacts of invasive plants	5-8	Students will be able to describe the food needs of a species of Montana's wildlife and identify the impacts that noxious weeds can have on its population.	Students role-play foraging elk and gather cards representing different types of food. They then calculate their food intake and how the presence of spotted knapweed might affect food availability for elk.

❋ Denotes lessons appropriate for the high school level Denotes service learning through hands-on involvement in invasive plant management

TAKING CONTROL AND LENDING A HAND:

Learning How Invasive Plants are Managed and Turning Knowledge Into Action

Lesson *Page*	**Title**	**Concepts Addressed**	**Targeted Grade Levels**	**Objectives**	**Description**
36 *p. 207*	**Stop That Weed!**	integrated weed management: weed control, noxious weeds	2-6	Students will be able to discuss ways that invasive plants (including noxious weeds) can be controlled and describe how unwanted invasive plants compete with native plants.	Students learn about methods of weed control while participating in games in which players represent roles in weed control scenarios.
37 *p. 211*	**The Great Race for Survival**	plant ecology, invasive species ecology, and weed management	3-8	Students will understand that invasive plants compete with native plants for resources, and can often spread aggressively and negatively impact native plant populations.	Students participate in a game in which each person represents a noxious weed or a native plant. Environmental factors are introduced, illustrating how invasive plants can outcompete native plants in a new environment.
38 ❋ *p. 213*	**Spotted Knapweed and Gall Fly Lab**	invasive species, weed management	6-12	The students will be able to define the term noxious weed. They will be able to explain what a biological control agent is and how it is part of Integrated Pest Management. They will also be able to explain or draw the life cycles of spotted knapweed and a spotted knapweed gall fly.	The students dissect a spotted knapweed seed head infected by the Spotted Knapweed Gall Fly, observing and drawing a gall and larvae. They collect data on the numbers of galls per seed head and predict the number of gall flies that will emerge from 100 seed heads. The students count the gall flies that actually emerge from 100 seed heads in a cage and compare what they predicted to what they found.
39 *p. 219*	**Biological... *Control?:* Tweaking the Ecological Web**	ecological interactions, food webs, biological controls	5-8	Students will understand the potential effects of biological controls on non-target species in an ecosystem.	Students role-play different members of a Montana grassland food web, and use information collected by researchers in Montana to determine how the introduction of a biocontrol agent affects other members of the grassland community and even changes the occurrence of a deadly human disease.
40 ❋ *p. 229*	**Biological... *Control?:* Cascading effects of biological control of knapweed**	invasive species ecology, weed management, biological control, herbivory, human health impacts	9-12	Students will understand the direct and indirect effects of biological controls on non-target species in an ecosystem.	Students use cooperative learning to teach each other about the cascading effects resulting from an introduced biological control agent, involving the invasive plant knapweed, the biological control agent (gall flies), mice, and hantavirus.
41 ✋ *p. 241*	**Pulling Together**	integrated weed management: weed control, monitoring, site recovery, and education	K-6	Students will be able to describe a variety of methods that can be used for weed control. Students will be able to describe the weed control approach developed by the Bradley sisters.	Students engage in a weed pull to help native plants return to a weed-infested area. Students also illustrate or combine photographs from their weed pull session into a series of posters or a storybook that tell the story of the Bradley Method.

❋ **Denotes lessons appropriate for the high school level** ✋ **Denotes service learning through hands-on involvement in invasive plant management**

TAKING CONTROL AND LENDING A HAND:

Learning How Invasive Plants are Managed and Turning Knowledge Into Action

Lesson *Page*	**Title**	**Concepts Addressed**	**Targeted Grade Levels**	**Objectives**	**Description**
42 *p. 245*	**Burning Questions**	ecosystems, invasive species ecology, succession, weed management, controlled burning	5-8	Students will understand that soil insulates the roots and rhizomes of plants during fire, and many plants can survive even the most intense fires. Students will understand that many invasive plants can outcompete native or other desirable plants after a fire.	Students use a "model" to represent the soil layers surrounding plants during a burn in order to measure the rate and extent of temperature increase due to heating. One set of measurements (for one thickness of insulation) is obtained as a demonstration, then students gather additional data at an activity center.
43 *p. 249*	**Getting Control of the Weed Problem**	integrated weed management, weed control, plant ecology, plant life cycle	6-8	The students will: know how plants reproduce; be able to explain chemical, mechanical, fire and biological weed control methods; be able to design and conduct an experiment to simulate a weed control method; understand the problem with applying only one control method; and be able to explain what is meant by *Integrated Weed Management*.	Students investigate weed control methods through individual or small group experiments.
44 ✋ *p. 257*	**The Restoration Cycle**	integrated weed management, weed control, habitat restoration, plant biology	2-5	Students will be able to describe the seasonal cycle of plant restoration and explain the importance of long-term, continuous restoration planning.	Students will develop posters representing the cyclical (seasonal) nature of restoration work. The poster can serve as a timeline and display of the restoration project process. *This lesson could be used for planning a weed removal/restoration project as part of* ***Lesson 41: Pulling Together*** *in this guide, or other class restoration project.*
45 ✋ *p. 261*	**Managing Invasive Plants**	invasive plant management, weed management plans, career exploration, taking action	5-8	Students will understand that weed management is a complex issue that may require many different kinds of actions. They will realize that different people have different viewpoints about how to manage weeds, and that appropriate management may differ depending on the desired outcomes and the place.	Students brainstorm and discuss factors contributing to weed invasions and efforts that can help control weeds. They read about different perspectives on weeds and weed management, and may conduct their own interviews of people in their area. They develop their own weed management plan based on their knowledge of control methods and the desired outcomes for the area.
46 ✵ ✋ *p. 273*	**Invasive Plant Management: Plan to Action**	invasive plant management, weed management plans, career exploration, taking action	9-12	Students will understand that weed management is a complex issue that may require many different kinds of actions. They will realize that different people have different viewpoints about how to manage weeds, and that appropriate management may differ depending on the desired outcomes and the place.	Students discuss factors contributing to weed invasions and efforts that can help control weeds, using their discussions to complete concept maps on these subjects. They conduct their own interviews of people in their area with different perspectives on weeds and weed management. They develop their own weed management plan based on their knowledge of control methods and the desired outcomes for the area.

✵ Denotes lessons appropriate for the high school level ✋ Denotes service learning through hands-on involvement in invasive plant management

kNOweeds Lesson Index 2

SCIENCE STANDARDS AND SUBJECT AREAS

Lesson	Title	Targeted Grade Levels	National Science Content Standards	Montana Science Standards	Other Subject Areas
1	**Discovering Plants through Observing and Reading**	K-4	C	3	Reading, literature
2	**The Seed: It All Starts Here (Well, Almost All)**	K-4	A, C	1, 3	Math
3	**Who Needs Plants?**	K-8	E, F	4, 5	Social Studies, Health
4	**Making a kNOweeds Journal**	K-8	C, E, F	3, 4, 5	Writing, Art, Social Studies
5	**Montana's Native People and Plants**	K-4	F	5	History, Indian Education, Health
6	**The Story of the Bitterroot**	5-8	F	5	History, Indian Education, Health
7	**Traditional Uses of Native Plants**	K-12	F	5	History, Indian Education, Health
8	**We Grow Wheat and Eat Tortillas**	K-4	C, F	3, 5	Health, Social Studies, Agriculture
9	**Local Color: Dyeing with Plants**	6-12	B, E, F	3, 5, 6	Art, History, Chemistry
10	**Know your Neighbors**	K-8	A, C, E	1, 3, 4	Art, Language Arts
11	**Who Lives Here? Plants as Environments**	K-8	A, C, E	1, 3, 4	Technology
12	**What's in a Name?**	K-8	A, C, F	1, 3, 5	Language Arts
13	**A Weed by any Other Name...**	6-12	C, F	1,3	Social Studies
14	**Noxious or Native?**	2-8	A, C, E, F	1, 3, 4, 5	Language Arts
15	**The Key to Montana Weed I.D.**	4-8	A, C, E, F	1, 3, 4, 5	Technology, Language Arts
16	**We Can't Eat Weeds!**	5-12	A, C, F	1, 3, 5	Math
17	**Plant Adaptations**	K-8	A, C	1, 3	Technology
18	**Weed Success: A Bag of Tricks**	5-8	A, C	1, 3	Math
19	**Measuring the Competition**	K-5	A, C	1, 3	Math, Technology
20	**Investigating Plant Competition**	6-12	A, C	1, 3	Math
21	**Plant Warfare: Investigating Allelopathy**	9-12	A, C	1, 3	Math
22	**Who Drank All The Water?**	4-8	A, C	1, 3	Math
23	**A Grain of Rice and a Hillside of Knapweed**	4-8	A, C	1, 3	Math, Literature
24	**Hitching a Ride**	K-4	A, C, F	1, 3, 5	Social Studies, Technology
25	**The Knapweed Hitchhikers**	5-8	A, C, F	1, 3, 5	Literature, Social Studies, Technology
26	**Aquatic Invaders**	K-12	A, C, F	1, 3, 5	Social Studies
27	**Schoolyard Plant Safari**	K-8	A, C, E, F	1, 3, 4, 5	Art, Language Arts, Technology

SCIENCE STANDARDS AND SUBJECT AREAS *(continued)*

Lesson	Title	Targeted Grade Levels	National Science Content Standards	Montana Science Standards	Other Subject Areas
28	**Map Mysteries**	2-8	A, C, E, F	1, 3, 4, 5	Math, Technology
29	**Adopt-A-Nature Trail**	2-8	A, C, E, F	1, 3, 4, 5	Math, Technology
30	**Changes on the Land**	2-6	C, E, F	3, 4, 5	Math
31	**Virtual Survey of Invasive Plants**	7-12	C, E, F	3, 5	Geography
32	**Weed Detectives: Surveying for Invasive Plants**	9-12	C, E, F	3, 5	Geography
33	**Sampling Invasive Plant Populations**	9-12	C, F	3, 5	Math
34	**Weeds Are an Earthmoving Problem**	3-5	A, C	1, 3	Earth Science
35	**Wildlife Weed Woes**	5-8	C, F	3, 5	Physical Education, Math
36	**Stop That Weed!**	2-6	A, C, F	1, 3, 5	Physical Education
37	**The Great Race for Survival**	3-8	C, F	3, 5	Physical Education, Math
38	**Spotted Knapweed and Gall Fly Lab**	6-12	A, C, F, G	1, 3, 5	Math, Language Arts, Agriculture
39	**Biological...*Control?:* Tweaking the Ecological Web**	5-8	A, C, F, G	1, 3, 5	Math
40	**Biological...*Control?:* Cascading Effects of Biological Control of Knapweed**	9-12	A, C, F, G	1, 3, 5, 6	Math
41	**Pulling Together**	K-6	A, C, F, G	1, 3, 5	Math, Art, Literature, Language Arts
42	**Burning Questions**	5-8	A, C, F	1, 3, 5	Math, Physical Science, Earth Science
43	**Getting Control of the Weed Problem**	6-8	A, C, F, G	1, 3, 5	Math, Language Arts, Technology
44	**The Restoration Cycle**	2-5	C, F, G	3, 5	Social Studies, Art, Language Arts
45	**Managing Invasive Plants**	5-8	A, C, F, G	1, 3, 5	Math, Technology
46	**Invasive Plant Management: Plan to Action**	9-12	A, C, F, G	1, 3, 5, 6	Technology

kNOweeds Curriculum Conceptual Framework

The following conceptual framework outlines key elements addressed in this guide for integrating invasive plant species topics into the K-12 curriculum. This framework is organized into three main sections:

BUILDING BASICS consists of concepts related to the importance of plants to humans and the environment, as well as concepts of plant biology which are important for understanding invasive plant issues.

INTRODUCING INVASIVES adds understanding about the ecology of invasive plants and their impacts.

TAKING ACTION AND LENDING A HAND provides information about how invasive plants are managed and constructs awareness of how learners can use their knowledge to take action on invasive plants. This section also includes ideas about citizen science and working with groups, as well as resources to assist in learning and doing more.

BUILDING BASICS

Constructing Knowledge About Plant Uses and Plant Biology

1) **Plants are important: Values and Uses**
    a) Plants provide products that are of both sustenance and economic values.
        i) Wood Products
            (1) Historical use of plants for building materials
                (a) Native American teepee poles, brush shelters, etc.
                (b) Logs used before mills were available
            (2) Wood is an important building material in modern construction, and the wood and paper products industry is an economically important industry in Montana.
        ii) Food
            (1) Gathering
                (a) Food is gathered from wild sources for personal use as well as for sale. Gathering, along with hunting, is the oldest way that humans acquired food, and is still practiced in many parts of the world.
                (b) In Montana, Native Americans gathered a huge variety of plant foods, many of which are still gathered today.
                (c) Wild plants are gathered by many Montanans today for food, medicinal purposes, and crafts. Berry and mushroom gathering is of economic as well as personal value.

(2) Agriculture is Montana's primary industry in economic terms. It is also an important component of the social structure and cultural heritage of many Montana communities.

(a) Direct: Many human food crops are grown in Montana, primarily grains, legumes, vegetables, and cherries.

(b) Indirect: Hay and other feed crops support the livestock industry.

iii) Medicinal

(1) Native Americans used hundreds of plant species in Montana for medicinal purposes.

(2) Current uses of plants for medicine include Pacific yew for cancer treatment.

iv) Other products

(1) Fuels: biodiesel and ethanol are renewable transportation fuels which are being produced in Montana to increase efficiency, reduce vehicle pollution, and support Montana's agricultural and tourism sectors.

(2) Clothing: Cotton and a few other plants still supply much of our clothing and many other household goods.

b) Plants have aesthetic, recreational, and spiritual values to people.

i) Wildflower viewing, forest recreation, gardening, cooking, art, and nature observation are some of the ways in which plants enrich people's lives.

c) Plants play vital ecological roles to sustain life.

i) Plants protect water sources and waterways:

(1) Plants hold soil in place, thereby slowing or preventing erosion and stopping sediments from entering streams, benefiting humans and aquatic life.

(2) Plants absorb toxins: Pollutants such as metals, oils, fertilizers, and microbes are filtered out of water by plants as water moves through wetlands, riparian areas and forests.

ii) Plants provide oxygen that is necessary for all animals on earth.

iii) Plants slow the effects of global warming by sequestering carbon.

iv) Plants provide food and shelter for other organisms, including other plants, animals, fungi, microbes – pretty much everything else on earth!

2) **Plant Biology**

a) Anatomy: Plants all share certain anatomical characteristics. Plant anatomy, or "morphology", describes the structure and parts of a plant: the leaves, stems, flowers, roots, etc.

b) Identification and classification: There are standard terms used to describe the parts of plants. These terms are used to help classify and identify plants. Organisms can be classified according to life needs, behavior, physical characteristics, habitat requirements, etc.

c) Species: A species is a group of plants which are similar to one another and capable of interbreeding with one another, but not with others.

d) Needs and Habitats: All plants share basic needs: air, water, sunlight and nutrients. However, plant species vary in how they acquire and use those resources, giving them different habitat requirements. These habitat requirements determine, in part, where different species of plants live. Habitat is composed of many integrated components.

e) Plant Distributions: Plant scientists use many methods to study plant densities (the number of plants in a unit area) and patterns, or the way plants are distributed in space.

f) Life histories: Plants have patterns of growth, reproduction, and lifespan that vary from species to species, and are associated with requirements for survival in particular conditions.

   i) Life cycles refer to the number of growing seasons an individual plant lives (annual, biennial, or perennial). All living things, including plants, go through various stages of life cycles.

   ii) Growth form describes the general size, woodiness, and general leaf shape.

   iii) Reproductive strategies: some species reproduce by seed, others vegetatively, and some use both strategies.

g) Populations and demography: A plant population is the group of individuals of a species living in an area small enough that they can all interbreed. Demography is the study of how plant populations change over time.

h) Plant Interactions: Plants may interact in ways that have positive or negative effects.

   i) Competition has a negative effect on both plants that use a resource in short supply.

   ii) Amensalism has a negative effect on one plant but doesn't affect the other. Examples may include detrimental shading of one plant by another, or allelopathy, in which one species releases a chemical harmful to another.

iii) Commensalism has a positive effect on one plant but no effect on the other. An example is the beneficial shading of one plant by another.

iv) Mutualism is an interaction that favors both plants, such as nitrogen fixation.

v) Parasitism occurs when one plant lives in or on another and receives nutrients from its host, benefiting the parasite to the detriment of the host.

i) Communities: Plant species living together in a habitat comprise a plant community. Communities are described by many features, including species lists, how those species are distributed spatially, and the physical structure of the vegetation. Species diversity refers to the richness and distribution of species in a community.

j) Ecosystems

i) Plants and other ecosystem components are often interdependent and interact in sometimes complex ways. Plants support a diverse assemblage of other species, and form the basis for the rest of the web of life in an ecosystem.

ii) Abiotic components interact with biotic ones.

(1) Rock and soil cycles, water, climate, and weather all influence habitat for plants, and in turn are influenced by plants and other life forms.

k) Geographical features are integral components of suitable habitat for plants and other life forms. Geographical mapping is a powerful tool for understanding and tracking distributions of plants and other organisms.

INTRODUCING INVASIVES

Learning About Invasive Plant Ecology and Impacts

3) **Invasive Species Ecology**

a) Introduction:

i) There are many definitions of weeds and many words and terms used to describe invasive plant species: weeds, exotic, non-native, non-indigenous, introduced, alien, and noxious.

(1) Exotic, introduced, non-native and non-indigenous refer to a species that has been introduced by humans to a place outside

its natural or native range. Some of these can be very beneficial to humans, such as garden species or food crops.

(2) A weed refers to a plant that is growing in an area where it is unwanted.

(3) An invasive species expands rapidly into new environments and persists there. Generally, these species displace native or other desirable vegetation, and may cause considerable environmental and economic harm. Only about 1% of non-native species become invasive. Harmful invasive species may also be called noxious. In Montana, there are laws mandating the control of noxious weeds.

ii) There is a variety of perspectives on the harmfulness of non-native and even invasive species. Some invasive species may have both negative and positive effects.

b) Mechanisms of invasion

i) Release from native limiting factors: When a species is removed from its natural habitat to a new one, it often leaves behind all the other organisms with which it has evolved for millions of years. These include herbivores, parasites, and pathogens.

ii) Plants are introduced by humans to areas outside their native range in many ways. Some species that are introduced for horticultural purposes "escape" domestication and become invasive. Seeds and other plant parts capable of regeneration are carried by clothing, vehicles (including boats and planes), soil, animal feed, seed mixes, pets and livestock, and water.

iii) Attributes of invasive species: Invasive plant species generally share some attributes that allow them to establish and spread where they do not occur naturally. These traits enable them to establish themselves quickly in disturbed environments and crowd out other species. Characteristics favorable to thriving in a disturbed environment include rapid growth, abundant seed production, persistent seeds, high germination rates, and tolerances for a wide range of environmental conditions.

iv) Human factors: A variety of human activities favor invasive species. Most of these involve altering natural plant communities and disturbing ground:

(1) Clearing ground for roads, trails, buildings and agriculture

(2) Overgrazing by livestock

(3) Removal of predators which allows herbivorous prey species to overpopulate

(4) Global climate change alters the environment in ways that tend to favor plant invasions.

v) Natural factors: Some natural processes such as fire, flooding, and wildlife grazing may favor the spread of invasive species.

(1) Resistance: The ability of a community to avoid change in the face of a disturbance.

(2) Resilience: The ability of a community to recover from change.

4) Impacts of Invasive Plants

i) Ecological impacts:

(1) Impacts to plant species: Invasive plants can reduce the numbers of other plants, occasionally to the point of eliminating them entirely from an area. Rare or endangered plants may be at risk from invasive plants. Plant invasions may also affect the genetics of native plants by hybridizing with them.

(2) Effects on plant communities: Invasive species can decrease the richness of native plant communities, turning diverse natural areas into near monocultures.

(3) Impacts to wildlife: Invasive plants can degrade or eliminate the vegetative basis of natural habitats, negatively impacting a large variety of fauna, from soil organisms, invertebrate and vertebrate pollinators, herbivores, and seed-eaters, to the predators which feed on all of these.

(4) Effects on ecosystems: Plant invasions may alter ecosystem processes such as fire cycles, erosion, sedimentation of waterways, water cycles, and nutrient cycles.

ii) Economic impacts

(1) Invasive plants cause millions of dollars of loss to Montana's economy every year.

(2) Plant invasions affect the economy by reducing agricultural production, recreation and tourism, and land values and causing related job losses.

(3) Invasive plants also cost millions of dollars to control.

iii) Benefits of weeds: Invasive species may have some positive ecological and economic effects.

(1) Invasive plants may be used for food, medicine, or agricultural products (e.g., honey).

(2) Invasive species may provide ecological services in the absence

of native species, such as slowing erosion or providing habitat (e.g. tamarisk and songbirds)

5) **Invasive plants in Montana**
   a) Montana currently has 34 plant species listed as noxious weeds. There are other species that show invasive tendencies, but have not yet colonized sites in Montana.
   b) Information about Montana's invasive species can be obtained from a variety of sources (see listing in this guide).

TAKING CONTROL AND LENDING A HAND

Learning How Invasive Plants are Managed and
Turning Knowledge into Action

6) **Weed Management**
   a) Federal and state laws regulate the spread and control of weeds in Montana. Laws related to endangered species and pesticide use are also related to invasive species.
   b) Weed management is the responsibility of private landowners, various branches of federal, tribal, state, county and city governments, non-profit organizations, and concerned citizens.
   c) Integrated Weed Management is the use of a variety of methods to manage weeds. It is generally the most effective way to achieve long-lasting results in limiting weed species. Some or all of the following may be used in integrated weed management.
      i) Weed management plans. Having a carefully thought-out and adaptive plan for weed management increases long-term effectiveness and may lower long-term costs. A plan identifies land management goals, the site's desired plants, and weed management objectives; assesses management options and strategies; determines monitoring methods; and assesses costs.
      ii) Surveys, inventories and mapping. Collecting data on weed occurrence, distributions, and population changes helps identify needs and priorities and set goals for management. There are several standard methods used to collect reliable data on plant locations and numbers.
      iii) Prevention is the most effective and efficient way to manage invasive plants. Prevention includes controlling the movement of seeds; minimizing the disturbance of desired plants; maintaining diverse, robust plant communities through good management practices; monitoring areas at risk; and restoring disturbed areas with native or other desirable vegetation.

iv) Control methods vary depending on what weed species is being controlled, where it is, what the objectives for control are, and who is responsible for control. Each control method has pros and cons, and some are short-term solutions while others have longer term effects.

(1) Manual and mechanical techniques include pulling, mowing and digging.

(2) Biological controls are plant-attacking organisms such as insects and pathogens which are introduced from the invasive plant's native range. They are carefully chosen to be host-specific to minimize potential damage to non-target species.

(3) Targeted grazing uses carefully controlled grazing by sheep or goats to control weed species.

(a) Grazing is usually timed to maximize damage to targeted species while minimizing damage to native or non-target plants.

(b) Grazers may need to be "trained" to consume some weed plants.

(4) Controlled burning uses fire to destroy plants in a targeted area, and works primarily on annual grasses.

(5) Herbicides are chemicals that stop or retard the growth and/or reproduction of plants.

(i) Herbicides usually act quickly and effectively. Must be reapplied every 2-4 years depending on the plant species, residual, and site. Herbicides are selective and non-selective.

Selective herbicides do not impact target grass species.

Non-selective herbicides impact all plant species.

(ii) Plants may evolve resistance to herbicides if the same herbicide is used over a long period of time on the same plant. This can ultimately render them less effective.

(iii) Herbicide use can allow invasive annual cheatgrass to thrive and also impact forb (broadleaf plant) reproduction.

(iv) Herbicides can have adverse effects on the health of humans and the environment, particularly if not used according to labeled directions.

(v) Monitoring allows managers to assess the effectiveness of efforts to control invasive species and to adapt management practices as needed.

(vi) Site recovery may include removing invasive species; planting native or other desired species; stabilizing soil; tending and protecting newly established vegetation; and altering site management. Types of site recovery include:

(1) Restoration: Return to exact ecological condition prior to disturbance.

(2) Reclamation: Construction of site to provide pre-disturbance functions. Emphasis on soil remediation.

(3) Rehabilitation: Return site to functioning system. Emphasis on plant ecological function.

(4) Revegetation: Restricted to the vegetation phase of all of the above.

(5) Research provides the knowledge used to manage invasive plants in the most effective and ecologically sound ways. Good communication among plant scientists and between scientists and managers is essential to integrating research and management.

(vii) Education is a vital component of weed management.

(1) Education efforts include disseminating information about the significance of invasive species and how to prevent their spread to the general public, students, landowners, and those charged with managing public lands.

(2) Education may take many forms, such as presentations, field trips, printed materials, and websites.

7) **Education** builds the capacity of individuals or groups to address weed issues on private and public lands.

a) Mentoring

i) Mentoring promotes the responsible usage of land and resources by teaching others about sustainable land stewardship and the importance of healthy ecosystems.

ii) After learning about sustainable land stewardship and the importance of health ecosystems, the "mentored" then mentor, continuing the positive exchange of knowledge and cycle of learning.

b) Community Outreach
  i) The sustainable usage of land requires the involvement of the entire community.
  ii) Those already trained in the importance of healthy ecosystems share the message with other community member via demonstrations, pamphlets, posters, presentations, publications, etc.

8) Agency Support

a) Land management agencies are charged with managing land and resources for the enjoyment of present and future generations.

b) Land management is a substantial task in the West, given the large amount of public land. Only with the help of community members and land users can agency land managers effectively stay abreast of the diverse land issues with which they are continually faced.

9) Citizen Science and Service

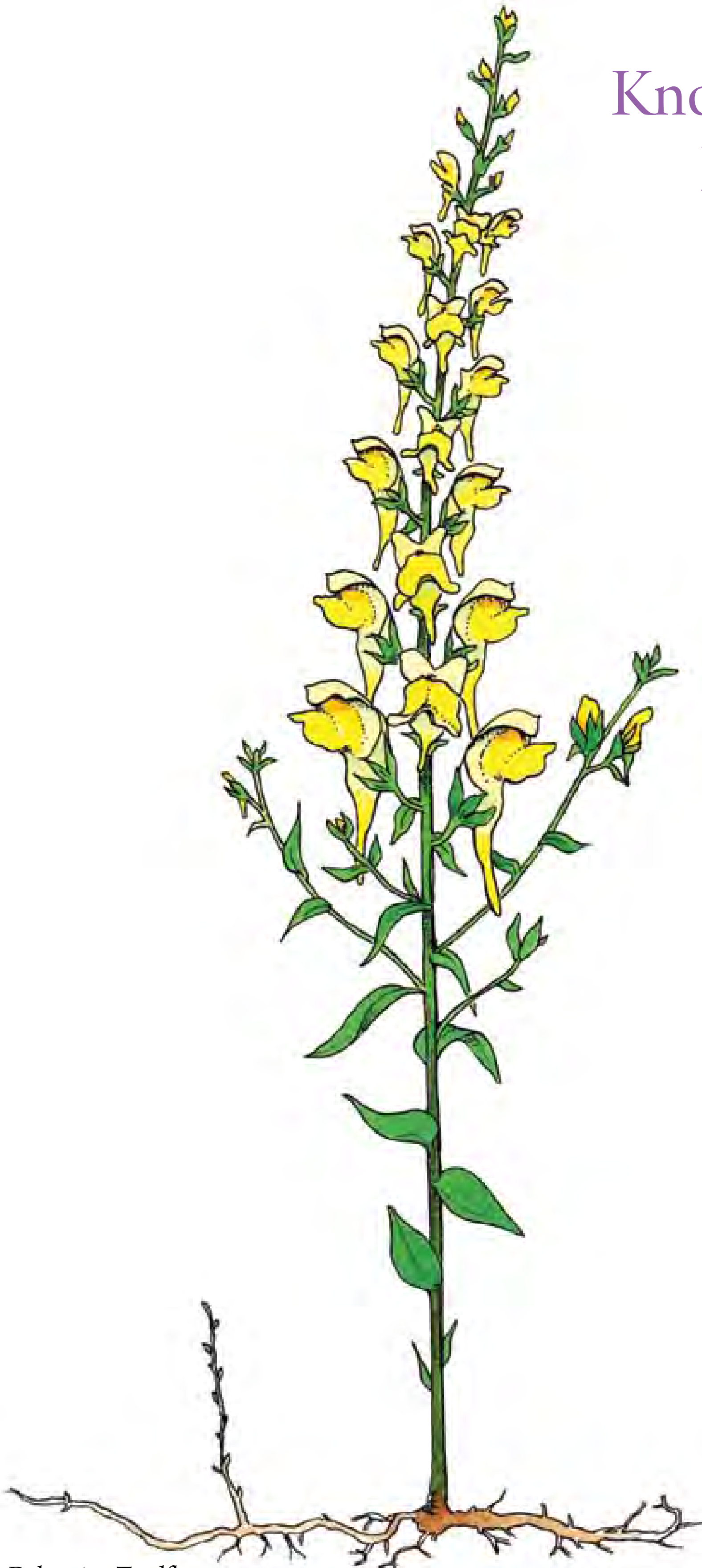
  i) Students can survey, record and map native and invasive plants in their community or natural area. Such information can be used directly by students as well as shared with those responsible for invasive plant management.
  ii) Students can partner with natural resource managers from local governments and organizations to help research and manage weeds.
  iii) Students can present information about native plant communities, invasive plants, and weed control to a variety of audiences in a variety of ways.

10) Resources and organizations

a) Federal, state, county, city and tribal government agencies and offices and private organizations are responsible for invasive plant research, management, and education.

b) There are repositories or central sites for contributing information collected on invasive plants.

BUILDING BASICS:
Constructing Knowledge About Plant Uses and Plant Biology



Dalmatian Toadflax
Linaria dalmatica

kNOweeds

LESSON 1

Discovering Plants Through Observing and Reading

Grade level: K-4
Subject Areas: Biology, language arts, literature
Duration: 30-45 minutes
Setting: Classroom
Season: Any
Conceptual Framework Topics: Plant life cycles, habitat

OBJECTIVES

Student will be able to identify needs and characteristics of plants and understand how they commonly reproduce.

METHOD

Students share their collective knowledge about plant biology while examining a real plant, and then together read a story (*The Tiny Seed*) and discuss what they have learned about plants.

MATERIALS

- ✎ A live potted plant
- ✎ The book *The Tiny Seed* by Eric Carle
- ✎ Hand lenses

BACKGROUND

All plants share certain characteristics as well as environmental challenges. Plant anatomy, or "morphology", describes the structure and parts of a plant: the leaves, stems, flowers, roots, and smaller components. All plants need sunlight, air (oxygen and carbon dioxide), water, and nutrients. Plants make their own food by converting water and carbon dioxide into sugar, using sunlight as energy, through the process of photosynthesis. Oxygen is released as a byproduct. Plants take water and nutrients in primarily through their roots, and sunlight and air enter through their leaves (roots also take in oxygen from the soil). Chlorophyll, a substance which makes photosynthesis work, also gives leaves their green color. In respiration, plants use oxygen to convert the sugars into energy for growth and metabolic processes.

Most plants reproduce by seeds, which are formed when flowers are pollinated. Seeds leave the parent plant by a variety of methods. Some simply drop to the ground below or near the plant. Others are carried by wind, water, or animals. If they end up in a place where the conditions are appropriate for germination, they grow. Alternately, they may be eaten, crushed, parched, drowned, or otherwise die.

Extensions
Read *How a Seed Grows* by Helene Jordan

Do ***Lesson 24: Hitching a Ride*** in the kNOweeds Guide

PROCEDURE

1. Start the lesson by asking students what they can tell you about plants. (Responses might include: They grow in dirt, they are green, they have leaves).

2. Ask students to closely examine a plant and make observations together about its characteristics. You may want to use guided questions to help them think about what they see and why plants are the way they are:

- What parts of the plant can you name?
- What are the leaves for?
- Why are they green?
- Are there parts you can't see? Where are they? What are they called? What do the roots do?
- Can plants move? How can they avoid being eaten or crushed?
- What makes them grow? How do they "eat"?
- How do they reproduce, or make more plants?
- Why do some plants have flowers?

3. Now read aloud *The Tiny Seed*, a book by Eric Carle.

- Do all seeds turn into plants?
- Why not?
- What are some of the things that can keep a seed from becoming a plant?
- What do seeds need to grow?
- Do all seeds grow below the parent plant? How do they get to other places? (Some travel by wind, as in the story. Others are spread by water, animals, humans, etc.)

LESSON 2

The Seed: It All Starts Here (Well, Almost All)

OBJECTIVES

Students will understand that most plants start from seeds, but some also start from tubers or bulbs. They will realize that there are many different types of seeds and they will learn to recognize the parts of seeds and their functions.

METHOD

Students examine different types of seeds and bulbs, figuring out what plants they come from. They observe and dissect lima beans, learning how water affects seeds and identifying the seed parts and their functions.

MATERIALS

- ✎ A variety of different kinds of seeds, such as apple, peach or plum, pepper, rice or wheat, nuts, melon or squash, pumpkin, and 2 dried beans (e.g., lima, pinto, or kidney) for each student.
- ✎ Hand lenses
- ✎ Tubers, such as potatoes, and bulbs, such as onions
- ✎ *Oh Say Can You Seed* by Bonnie Worth (optional)
- ✎ *How a Seed Grows* by Helene Jordan (optional)

BACKGROUND

The way plants reproduce is a fascinating process. Out of the more than 300,000 different kinds of plants, more than half are seed plants. Seed plants make their own seeds from which new plants grow. Other ways plants can make new plants are from spores, rhizomes, bulbs, tubers, corms, cuttings, grafts, and buds. Seeds are produced in flowers in some plants and by cones in other plants.

Plant seeds may appear like simple spheres, but seeds actually have very specialized parts. The seed coat, the hard outer layer, protects the seed. Inside are stored food and a plant embryo waiting for the right conditions to grow. Moistening seeds can create changes in the seed as it starts the growing process and makes it easier to examine a seed.

Grade level: K-4
Subject Areas: Biology, language arts
Duration: Two 15-minute sessions on consecutive days or one 30-minute session
Setting: Classroom
Season: Any
Conceptual Framework Topics: Life cycles, plant anatomy, growth, reproduction

Extensions

Soak several beans and keep them in damp towels for several days. Every day or every other day, dissect a bean and see how it grows.

Sprout a potato in class so that students can see the plants growing from the eyes. Place the potato in a warm, dark place and check it daily. Have your students predict how long it will take and which eye(s) will sprout.

Read and discuss the book *Oh Say Can You Seed* by Bonnie Worth.

Read together the picture book *How a Seed Grows* by Helene Jordan. Follow the experiments suggested in the book.

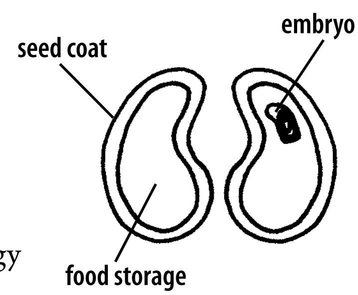
What do seeds need to grow? Lead a discussion by starting with "What do children need to grow?" Then, ask the students what they think plants might need. Sprout a seed in a jar/clear plastic cup with wet paper towels. (You may want to use a bean seed, alfalfa, or popcorn.) Put some of the seeds in a windowsill to sprout. Put others in a dark corner. Discuss with the students which of the seeds they think will grow the best. Check periodically to see if their predictions match what they see.

PROCEDURE

1. Begin by asking students what they know about seeds: where they come from, what they are for, what they look like. Now show them the collection of different seeds and ask them which ones are seeds. Discuss with them that different plants produce different kinds of seeds, and that they are all seeds.

2. Give each student 2 beans. Have them observe them closely and describe what they look and feel like. Then have them soak one of their beans in water over night. You can have them wet a paper towel with water and fold it over around the bean; make sure the towel is pretty wet. (It is a good idea to soak some extras yourself). Alternatively, to do this in one class session, you can soak half the beans the night before and simply give each student one dry bean and one soaked one.

3. Have students use a hand lens to examine the outside of the soaked bean. Have them describe how it looks and feels. Compare it to the dried bean. Show them how to peel off the seed covering of the soaked bean. Split them in halves with fingernails (you may need to help younger students with this). Have them draw what they see.



4. On the board draw the bean halves showing the seed coat, embryo, and food storage labeled. Ask if they can figure out the roles of the different parts. (The seed coat protects the seed until it is ready to grow. The embryo grows into the plant using the stored food for energy to grow until it can get energy from the sun.)

5. Some seeds grow from other plant parts (*tubers*, like potatoes, and *bulbs*, like onions). These also are the part we eat. Show the students some of the foods that we eat that are tubers (potatoes) and bulbs (onions). Ask if they know what part of the plant these are from (roots). Discuss with students why they are so big, unlike most roots (food storage). Ask if they know how potato plants are started. Discuss how plants like onions can sprout a new plant from the food stored in the bulb. Can they think of any advantages of reproducing this way? Disadvantages?

LESSON 3

Who Needs Plants?

OBJECTIVES

Student will be able to name 5-10 everyday objects that are made from or possible by plants.

METHOD

Students make lists of objects in the classroom that are made (directly or indirectly) from plants. They take home a sheet on which to record their dinner and what parts of it come from plants, or they can do this step with their lunch.

MATERIALS

✎ **Plants or Not?** Activity Sheet

BACKGROUND INFORMATION

Many of the products used in our everyday life are made from or made possible by plants. All of our food, with the exceptions of salt and a few other mineral items (baking soda, etc.) and fungi comes from plants either directly or indirectly (as feed for animals we eat). Plants also give us paper products (books, newpapers, wallpaper, money), wood (furniture, buildings, tools, fencing, sports equipment, fuel, boats, musical instruments, plywood, particle board), cardboard, much of the fabric used for clothing, bedding, rugs, carpet, curtains, furniture, some dyes and inks, adhesives, packing materials, rope, string, yarn, medicine, cleansers, rubber (toys, erasers, tires, boots, shoes, gloves, mechanical parts), cork, and other products. Even petroleum products (oil, gasoline, plastics) would not be possible without plants, the remains of which were made into petroleum through geological processes that applied heat and pressure to them.

PROCEDURE

1. Begin by asking your students to write the names of 10 items in their classroom, each item on a separate small piece of paper. When they are finished, ask your students to name some items humans use which are made from plants. For older students, you may want to ask them to estimate the percentage of classroom items made directly or indirectly from plants.

2. Now hand out the **Plants or not?** activity sheet. Working individually or in small groups, have your students look carefully around the room and make lists of items according to whether they are made from plants or plant-derived materials or not.

Grade level: K-8
Subject Areas: Biology, technology, social studies
Duration: 30 minutes in classroom, 10 minutes at home (or at lunch)
Setting: Classroom
Season: Any
Conceptual Framework Topic: Plant values to people

Extensions

Have your students list all the things they can think of that come from plants. You might give them categories to help them: building materials, sports equipment, paper products, health products, etc.

Besides people, animals also need plants. Discuss with your students: what do you think animals use plants for?

Have your students (or do this as a class) research unusual plant uses on the internet. They may want to check out *Plants for a Future* at **http://www.pfaf.org/index.php** or the UBC Botanical Garden at **http://www.ubcbotanicalgarden.org/weblog/cat_novel_uses_of_plants.php** to learn about some fascinating and unusual uses for plants!

3. Now ask students if they know what plastic is made from. If no one knows, tell them that most plastics are made from petroleum, or oil. Ask them if they know what oil is. If necessary, explain that oil was made by nature when tiny plants (and animals) died in the ocean millions of years ago. They sank to the bottom of the sea and were mixed with mud and silt. Over time, hundreds of feet of mud containing the organisms accumulated. As more mud piled on top of them, over millions of years, heat and pressure deep underground changed them into petroleum. So even some plastics, made from petroleum, come from plants! Does this change their assessment of which items are derived from plants?

4. After your students have had a chance to fill out their sheets, work as a group to create a class list of all the plant-based items vs. non-plant-based items. Which are there more of? Estimate about how much of the entire room and its contents are made from plant materials.

5. This step can be done with your students' lunch or they can take their data sheet home and do it at dinner. Have them make a list of the foods they eat at their meal. Make separate lists of plant-based foods and non-plant-based foods. For processed (packaged) or complex foods, have them look at the list of ingredients and determine if they come from plants or not. (Some ingredients, such as preservatives or food coloring, might be difficult to determine. They may want to have an "unknown" column.)

6. When you reconvene, as a group discuss the lists. How much of their food comes from plants? (This should be almost 100%, including meat.) Make sure they realize that even items like candy and snacks are, at least in part, made from plants (terms like modified starch, sucrose, vinegar, corn syrup, etc. may not be easily recognizable as such).

7. They could make a bar graph or pie graph with their papers of 10 items, plant-related items and non-plant items. (Remove any repeated items.) If you had them estimate percentages before they started, they could compare the actual result with what their original percentage guess was.

8. Ask your students how important they think plants are to their lives. Would they be able to get by without plants? What could they eat? What could they build a house out of? How would they get around? What could they play with?

Name ____

Plants or Not?

Look around your classroom! Do you think most of the things in your room are made from plants? Look carefully at the items in your room and try to figure out whether they are made from plants or not. Then list them in the appropriate column, based on your decision.

Category	**Plant-based items**	**Non-plant-based items**
Building	1 2 3 4 5	1 2 3 4 5
Furniture	1 2 3 4 5	1 2 3 4 5
School materials	1 2 3 4 5	1 2 3 4 5
Classroom equipment	1 2 3 4 5	1 2 3 4 5
Others	1 2 3 4 5	1 2 3 4 5

LESSON 4

Making a kNOweeds Journal

OBJECTIVES
Students know the importance of wood products to people and the process of how paper is made as they make their own kNOweeds Journal. Students are able to use the journal as a tool for scientific journaling.

METHOD
Students create a field journal for use on class field studies or on their own. ***The kNOweeds Guide offers a number of lessons that would be enhanced by the use of student field journals.***

MATERIALS

- Hole Puncher
- Blank Unlined 8.5" x 11" Paper
- Cardboard
- Card Stock
- Twine
- Scissors

MATERIALS FOR PAPERMAKING *(optional)*

- Papermaking mold (screen) and deckle. Kits are available from craft shops, art supply stores, and toy stores
- Toilet tissue, facial tissue, paper towels, or paper from the recycling bin
- Large mixing bowl
- Wire whisk or hand egg beater
- Large plastic bin large enough to accommodate the papermaking mold and deckle
- Kitchen towel, newspapers, or paper towels, folded
- Spatula
- Rolling pin
- Cookie sheet or other flat surface
- Dried flowers or leaves (optional)

Grade level: K-8
Subject Areas: Science, art, forestry
Duration: 45 minutes, additional class session needed for optional papermaking activity
Setting: Indoors or Outdoors
Season: All
Conceptual Framework Topic: Plants provide products of economic value.

BACKGROUND
A journal is a useful tool in the study of plants and the problems associated with invasive plants. Scientists use journals to keep written records of their work. *Scientific journaling* provides a method for students to record and understand science phenomena. Students gain the following skills through regular use of scientific journals:

- Making observations
- Recording events
- Communicating understanding of concepts
- Communicating observations and ideas
- Developing organizational skills
- Developing questioning abilities
- Practicing and developing fine motor skills
- Expressing information in graphic forms
- Analyzing data
- Linking disciplines
- Communicating classroom activities with parents
- Reflecting on what they have learned

A kNOweeds Journal can be used for a wide range of expression and serve as a tool for students to learn skills in science through discovery and record-keeping. Sketches are a quick way to capture the way things look. Written observations can serve as the basis for a great range of scientific as well as creative writing.

PROCEDURE
Making kNOweeds Journals

1. Guide students in the creation of a half-sheet sized field journal for each student. You may elect to further the lesson of the value of plant resources by having students make their own paper for their journal cover, similar to the papermaking process used when trees are processed into paper or waste paper is recycled.

2. *Optional: To make the cover from recycled paper and perhaps other plant material, students will follow steps a-f below. Otherwise, cardstock can be used and you can proceed to step 3.* This activity can be messy so ask students to wear old clothes. If it's a nice day, you may do this activity outside. If you are inside, place a layer of newspapers on the floor underneath your work area. Before you begin, gather all of your supplies together and put them out on the counter. Read all of the directions from start to finish to become familiar with the procedure, then proceed as follows:

a. Tear up about 4 cups of paper (no glossy paper such as found in magazines) into pieces about the size of a postage stamp. Place these into the mixing bowl. Next add enough warm water to cover the paper (about 1-2 cups should do). Watch as the paper starts to absorb water and break down into soggy mush. What you are seeing is the wood fibers in the paper separating from one another. Papermakers call this mushy solution "pulp."

b. Using the wire whisk or hand egg beater, mix the pulp until the fibers are separated and evenly distributed. No large clumps should remain. You may use your hands to break apart any remaining lumps.

c. Pour the pulp into the large plastic bin, and add more water until the bin is about half full. This watery mixture is called slurry. Stir the slurry around with your hands. The consistency should be similar to very thin oatmeal. The thicker the slurry, the thicker your piece of paper will be. If it is too thick, add more water. If it is too thin, make another batch of pulp and add it to the slurry a little at a time until it reaches the desired consistency.

d. Fold the kitchen towel, newspapers, or paper towels into a thick pad (about 1 inch thick) and about the size of your papermaking screen, and place it on the cookie sheet. This pad is called a couching (pronounced "cooch-ing") mound.

e. Pour the slurry onto the screen until the screen is covered with a complete layer. Press the moisture through the screen, which will allow a layer of damp paper to be left behind against the screen. Decorate with leaves or flowers while damp by pressing them into the slurry as desired. Turn your damp sheet of paper onto the couching mound. Allow to dry before handling.

f. Use this handmade paper in the creation of a cover for your journal.

3. Holes can be punched through the pages and cover to provide a place to bind or tie together the journal using twine, thin wire, or other materials. As the journals are being put together, you can discuss with students the importance of forest products in Montana, and ask students to brainstorm a list of wood products, such as materials they are using to make their journal, that are important in their lives as you record them on the board.

Using the kNOweeds Journal

A number of the lessons in the kNOweeds Guide call for journals to be used. The following are tips for implementing the use of science journals with students:

Oxeye Daisy
Chrysanthemum leucanthemum vulgare

1. Select a format that works with the goal or activity such as quick experiments, studies around a theme, or ongoing observations. Depending upon the learning goals it is possible to have multiple journals/notebooks in process at the same time. For example – the class might have a weather log; each student might have a daily nature observation log, and a journal for a specific topic such as invasive plants.

2. Date entries – concepts can be built upon and lead to the analysis of patterns. Dating entries helps to reinforce the importance of regular journal entries.

3. Drawings are an important part of the notebook as they help students express complex ideas.

4. Provide a context before the lesson or activity and include ideas about what the students might observe, write, or draw in their notebooks.

5. Keep your own notebook and share it with the students. This will help you understand what the students are experiencing.

6. Make routine observations – same time daily, weekly or monthly. This helps students see patterns and analyze changes. Observation topics might include the environment, weather, seasonal changes, the view from the classroom window, the students' height.

7. Allow time during activities and experiments for students to record observations.

8. Observe how students are recording information – use those observations to guide future activities. For example, if students are mainly writing and not drawing, explain the importance of visual representations for the information.

9. Before assessing the notebooks, determine what needs to be assessed: scientific content, observations made, writing and grammar, or other aspects.

10. Have students use journals to share what they have learned and their understanding of the topic with other students and their parents. This helps reinforce their understanding of the material and can help identify any misconceptions the students might have.

11. Use the journals for other assignments and projects. For example, if the students are writing a paper on their favorite animals, their science journal could be a place to record their research and observations or serve as a resource for information.

12. Encourage students to review previous journal entries to answer questions for new assignments or formulate observations based on their expanding experiences.

The following are some additional ideas for using journals as students learn about invasive plants.

I Think, I Saw, I Discovered
This method allows students to make predictions, record their observations and summarize the activity. The three topics for this type of entry are:

- Hypothesis – what they think will happen
- Observations – what they saw/observed, data, questions
- Conclusions – what they learned, their conclusions, their thoughts

This method is a good introduction to the scientific method and is appropriate for early elementary students.

I Know, I Wonder, I Learned, Now I Wonder
This method consists of four parts, with the emphasis on what is known and learned from the activity/experiment as opposed to the observations and conclusions. Students have a chance to express what they already know before starting and what new questions they have based on the experience.

The four topics to cover include:

- What they already know about the topic
- What they would like to learn about the topic
- What they learned during the activity/experiment/unit
- What additional questions were raised

This approach gives students practice with reviewing and monitoring their own learning.

"I Used to Think But Now I Know"
This method helps students record how their thinking has changed.

*I used to think*__________________*but now I know*__________________.

Extensions
Keep a ***kNOweeds Journal*** ongoing throughout the school year, using it as a record and reference during ***kNOweeds Guide*** classroom lessons, field trips, research assignments, experiments, and community projects. Have students individualize their journals with art, daily entries, and feedback about their experiences.

LESSON 5

Montana's Native People and Plants

Grade level: K-4
Subject Areas: Biology, language arts, history, social studies
Duration: Two 30-minute or one 50-minute session
Setting: Classroom
Season: Any
Conceptual Framework Topics: Aesthetic, recreational and spiritual values of plants, species, habitat, weed management

OBJECTIVES

Students will understand the importance of many plant species to Montana's native people. They will be able to describe the uses of 2 different native plants.

METHOD

Students read a Salish legend in which Montana's state plant, the bitterroot, played a vital part in survival of early people. They research use of plants and learn how other plants were and are used by Montana's native people.

MATERIALS

- ✎ *The Origin of Bitterroot: A Salish Plant Story* (follows lesson)
- ✎ Plant identification guides that include information on Indian uses of plants (see ***Resources*** section of this guide) or Internet access to use web sites such as Montana Plant Life at **http://montana.plant-life.org/index.html** or the Kootenai National Forest at: **www.fs.fed.us/r1/kootenai/resources/plants/plants/edible_medicinal/index.shtml**
- ✎ **Montana Native People and Plants** information sheet and a
- ✎ **Montana Natives: People and Plants** activity sheet (one of each per student)

BACKGROUND

In the old days, Indian people in Montana were dependent upon plants and animals for their livelihood. They knew the habitat and uses of most plants in their territory. If they came upon an unfamiliar plant in their travels, it was subjected to scrutiny and experimentation. It was, after all, a new gift from the Creator.

Knowledge of traditional plant use has been passed from generation to generation. That knowledge base continues to grow today. If a skilled native botanist is not able to find a use for a plant in a relatively short time, it is assumed that a use will eventually be discovered. Plant uses are sometimes revealed to worthy individuals through visions, dreams or as a gift from a spirit guardian; but most uses are determined through observation and testing.

Typically, a person known for powers as a medicine woman or medicine man will carefully test the properties of a plant. A new species of mint reveals a use to the sense of smell and taste. While nettles and thistles might have seemed a simple nuisance to the uninformed, upon observation of animals eating them and after testing, native botanists found uses for them as medicines, food, dyes and even material for fabric.

(Excerpted from "Work House" Activity Guide from Glacier National Park, used with permission).

American Indian plant uses were passed along to European Americans, often saving them from starvation or illness. On several occasions members of the Lewis and Clark Corp of Discovery would likely have starved without the knowledge of or actual food from native plants, given or traded to them by various Indian tribes. When Lewis and Clark expedition member William Bratton fell ill with back pain and coughing on Feb. 10, 1806, the explorers lost the capacities of one of their most valuable members. Bratton's health began to deteriorate during the Corps' stay at Fort Clatsop. Bratton suffered extreme lower back pains as the expedition started for home in March. By the time they reached the Great Falls of the Columbia in Oregon, in April, Bratton was semi-paralyzed and had to ride horseback while the rest of the group walked.

Bratton received a sweat bath treatment similar to the kind used by most tribes in North America at that time, and was given "copius draughts" of strong tea brewed from *horsemint*, a prolific member of the mint family with a range from the American Southwest to Canada, including Montana. This combined treatment was felt to have relieved Bratton from his back pain for the remainder of the trip.

In the early days, the Salish tribe was most at home in the intermountain valleys of western Montana. They had a balanced diet of plant foods and meat. They hunted in the mountains and spent time hunting buffalo on the plains. The Salish resided mainly in the valleys and had access to such root crops as bitterroot, camas, biscuit root, wild carrots, and onions.

The bitterroot is the state flower of Montana. The root was an important food for the Salish and other Montana tribes. The root is small and time consuming to collect in quantity, but it is very nourishing. Indian women usually dug the roots in spring as the leaves were developing, before the root became most bitter. They used special digging sticks made from fire-hardened branches and antlers. A 50-pound bag, enough to last one person for the winter, would take 3-4 days to fill. Some find the taste pleasant though a definite bitter flavor develops afterwards. If the root is stored for a year or two the bitterness is somewhat reduced. The roots were boiled or steamed, mixed with berries and meat, or dried, ground into powder, and used as a thickener.

Bitterroots grow in dry, gravelly soil in western and south central Montana. They can be prolific in some areas, creating a carpet of pink when in bloom. But they are vulnerable to disturbance, including invasion from invasive plants.

PROCEDURE

1. ***Ahead of Time:*** Read through the story and discussion questions and make copies of information and activity sheets.

2. Read the story *The Origin of the Bitterroot* aloud in class and lead your students in a discussion about the story. You may want to use the following questions:

- According to Salish legend, how did the bitterroot come to be?
- From the description in the story, can you visualize what the bitterroot plant looks like? (You might want to show them the illustration after they describe what they think it looks like.)
- How are the plant's features related to the Salish story?
- What could be some reasons the people in the story were starving?
- Do you think a plant like the bitterroot could save people from starvation?
- What time of year is the bitterroot dug for food?
- Can you think of any other natural objects in which their physical appearance or use by humans is explained by legends or stories? (e.g., The Man in the Moon, the "Just So" stories by Rudyard Kipling, constellations tied to myths)

3. Hand out the **Native People and Plants Activity Sheet**. Have your students color the bitterroot as you re-read the description in the legend to them. Have them read the description of how bitterroots were used and discuss this use in class. Ask your students:

- Do you think it would be hard to gather bitterroots to eat?
- Do you like the taste of bitter foods? Can you name some bitter-tasting foods you've eaten? (You might ask if they have tasted unsweetened chocolate or cocoa powder, and explain that chocolate is bitter until sugar is added.)
- Are there any wild plants that your family gathers to eat?
- Why do you think the bitterroot is Montana's state flower?
- Can you think of any issues to consider when digging up bitterroot plants now? (You might discuss possible harm to dwindling populations, private property rights, impacting traditional gathering grounds, allowing weeds to invade, etc.)
- How do you think weeds might affect plants like bitterroots? What kind of habitat does the bitterroot usually grow in? Do you know of any non-native, invasive plants (weeds) that grow in that same kind of habitat?
- How might the invasion of natural areas by non-native plants affect people like the Native Americans who have a strong cultural tie with the native vegetation?

4. Now have your students research another Montana plant that was traditionally used for food or medicine. You can have them use one of the resources listed or others you may find, and fill out the activity sheet with their own drawing and information. You may want to have them use the "Questions for Plant Research" as a guide when they research their plant.

Extensions

Have students present what they have learned to other students, parents, or community members.

Put the students' completed activity sheets together as a booklet on native plants for a class resource.

Present ***Lesson 7: Traditional Uses of Native Plants*** in this guide.

Have your students taste foods made from local wild plants, such as jams and jellies.

The Origin of Bitterroot

A Salish plant story

Long ago, when the Salish people still lived to the south in the area that is now called the Bitterroot Valley, there was a time of severe famine. In those sad days there lived a righteous old woman, the wife of a medicine man. The old woman grieved for her children who were slowly starving. With no meat and no fish to eat, her sons were doing their best to get by on some old dried up shoots of balsamroot. Even those were nearly gone.

"My sons have nothing to eat and will soon be dead", she sobbed. So she took herself down to the banks of the creek we call Little Bitterroot and laid herself down to mourn for her children. With her face to the ground and her old gray hair spread about her head she wept bitter tears as she wailed a song of death.


Nancy Seiler

As The Sun rose up over the mountains and peered down into the valley, he was greatly sorrowed to hear the old woman's death chant. The Sun called forth the guardian spirit of the woman and said, "Your daughter is in need. Go to her; give her comfort and bring forth food and beauty from that which is dead."

Assuming the form of a beautiful red bird, the guardian spirit flew down to the old woman and gently spoke to her. "Your bitter tears have soaked the earth beneath you. Even now they are mingling with the dead vegetation below to form the roots of a new plant. Its fleshy leaves will lay upon the ground and a beautiful flower will rise up to the Sun. Its blossom will share the silver-white color of your hair and the rosy hue of my wings. Your children will dig the roots of our gift plant. Though they will find its taste as bitter as your tears have been, they will know that it is good food and they will grow to love it.

Each year, in the moon of deep water, they will see the return of the blossoms and say, "See, there is the silver hair of our mother upon the ground and there are the rosy wings of the spirit bird. The love and bitter tears of our mother have provided us with food for all generations."

Montana Native People and Plants

Lewisia rediviva
Bitterroot or Bitterroot Lewisia

- The bitterroot is the state flower of Montana.
- The root was an important food for the Salish and other Montana tribes. The root is small and time consuming to collect in quantity, but it is very nourishing. It is said to be extremely nutritious, 50 - 80 grams being sufficient to sustain an active person for a day.
- Indian women usually dug the roots in spring as the leaves were developing, before the root became most bitter. They used special digging sticks made from fire-hardened branches and antlers. A 50-pound bag, enough to feed a person for the winter, took 3-4 days to fill.
- To some who taste it the root has a good taste, although others find it too bitter to enjoy. If the root is stored for a year or two the bitterness is somewhat reduced. The roots were boiled or steamed, mixed with berries and meat, or dried, ground into powder, and used as a thickener in soups and stews.
- Bitterroots are still collected by Indian people in western Montana today.
- Bitterroots grow in gravelly, dry soil in the plains and low mountains.

Illustration courtesy U.S. Forest Service Rangeland Management Botany Program

Name ____

Montana Natives: People and Plants

Common Name(s): ______________________________

Scientific Name: ______________________________

DRAW YOUR PLANT HERE

Questions for Plant Research

1. How is or was this plant used by Montana native peoples? What parts were used and how were they prepared for use? Did different tribes use it differently?
2. Were there any special ceremonies or rituals observed when gathering, preparing and using this plant?
3. Are there any special legends or traditional stories involved with the use of this plant?
4. How does the plant reproduce? How does it spread into new territory?
5. In what sort of habitat would you look for this plant?
6. Does your plant have any special relationships with other plants or animals? Is it particularly important to certain plants or animals?
7. Is it a rare or threatened species?
8. What other interesting information can you supply about your plant?

LESSON 6

The Story of the Bitterroot

OBJECTIVES

Students will understand the importance of the bitterroot plant to the Salish people of western Montana. They will realize how the plant is interwoven into the culture of the tribe, as well as learning about the plant's biology and the changes that have affected both the plant and the people over the past 150 years.

METHOD

Students watch a video about the Salish tribe and Montana's state plant, the bitterroot, and their interconnected story. They discuss the film using guided discussion questions, and research how other plants were and are used by Montana's native people.

MATERIALS

✎ The video *The Story of Bitterroot*, which was distributed by OPI to all Montana school libraries.

✎ Plant identification guides that include information on native uses of plants (see ***Resources*** section of this guide) or Internet access to use web sites such as Montana Plant Life at **http://montana.plant-life.org/index.html** or the Kootenai National Forest at **www.fs.fed.us/r1/kootenai/resources/plants/plants/edible_medicinal/index.shtml**

✎ **Montana Natives: People and Plants** activity sheet (one per student).

BACKGROUND

In the old days, Indian people in Montana were dependent upon plants and animals for their livelihood. They knew the habitat and uses of most plants in their territory. If they came upon an unfamiliar plant in their travels, it was subjected to scrutiny and experimentation. It was, after all, a new gift from the Creator.

Knowledge of traditional plant use has been passed from generation to generation. That knowledge base continues to grow today. If a skilled native botanist is not able to find a use for a plant in a relatively short time, it is assumed that a use will eventually be discovered. Plant uses are sometimes revealed to worthy individuals through visions, dreams or as a gift from a spirit guardian; but most uses are determined through observation and testing. Typically, a person known for powers as a medicine woman or medicine man will carefully test the properties of a plant. A new species of mint reveals a use to the sense of smell and taste. While nettles and thistles might have seemed a simple nuisance to the uninformed, upon observation of animals eating them and after testing, native botanists found uses for them as medicines, food, dyes and even material for fabric.

(Excerpted from *Work House* Activity Guide from Glacier National Park, used with permission).

Grade level: 5-8
Subject Areas: Biology, language arts, history, social studies
Duration: 2 or 3 class sessions, plus research time
Setting: Classroom
Season: Any
Conceptual Framework Topics: Aesthetic, recreational and spiritual values of plants, species, habitat, weed management

(Adapted in part from Montana's OPI *Indian Education for All* curriculum)

The bitterroot is the state flower of Montana. The root was an important food for the Salish and other Montana tribes. The root is small and time consuming to collect in quantity, but it is very nourishing. Indian women usually dug the roots in spring as the leaves were developing, before the root became most bitter. They used special digging sticks made from fire-hardened branches and antlers. A 50-pound bag, enough to feed a person for the winter, would take 3-4 days to fill. Some like the taste although a decidedly bitter flavor develops afterwards. If the root is stored for a year or two the bitterness is somewhat reduced. The roots were boiled or steamed, mixed with berries and meat, or dried, ground into powder, and used as a thickener.

Bitterroots grow in dry, gravelly soil in western and south central Montana. They can be prolific in some areas, creating a carpet of pink when in bloom. But they are vulnerable to disturbance, including invasion from noxious weeds.

The 64-minute DVD focuses primarily on the Montana Salish Indian culture, but interweaves themes common to both non-native and Native Americans. Native American tribal elders are the predominant source of information in the DVD. The video also contains sections on the bitterroot's biology, Lewis and Clark, and the story of it becoming the state flower.

The DVD is organized into eight discrete sections; each is individually accessible and has a title and a theme. Some sections are more relevant to native plant and weed education than others. Montana's OPI Indian Education for All website has a full curriculum guide to use with the video. That guide can be found at **http://www.opi.mt.gov/PDF/IndianEd/bitterroot_curr_alt.pdf.** Some of the discussion questions below are adapted from the OPI guide.

PROCEDURE

1. **Watch Section A:** *Legend of the Bitterroot* (6 minutes) of the OPI video "The Story of the Bitterroot" in class and lead your students in a discussion about the story. You may want to use the following questions:

   a. According to the Salish how did the bitterroot come to be? *(The creator provided it to save the starving people.)*

   b. How are the plant's features related to the Salish story? *(The silver of the flower is the color of the grandmother's hair, and the pink from the wings of the red-winged blackbird)*

   c. Who only can say the first bitterroot prayer? *(It has to be a woman. Women traditionally were gatherers of the natural foods.)*

   d. What is the traditional tool used to dig the bitterroot? *(A digging stick or petzah is used.)*

   e. What could be some reasons the people in the story were starving? *(Conditions like rain and temperature vary year to year, affecting the quantity of foods available.)*

   f. Do you think a plant like the bitterroot could save people from starvation? *(Bitterroots were very plentiful in some areas, and they are very nutritious)*

   g. Can you think of any other natural objects in which their physical appearance or use by humans is explained by legends or stories?

2. **Watch Section B:** *The Corps of Discovery* (12 minutes) and discuss:

   a. Who was the first white man to describe the bitterroot? *(Meriwether Lewis)*

   b. Why were the native plants, including edible ones, unfamiliar to explorers? *(They didn't grow in the eastern part of the country where they came from.)*

   c. What was the importance of the bitterroot to the Salish when Lewis and Clark passed through? *(The bitterroot was an important part of their diet and had great cultural significance.)*

   d. When the bitterroot was given its Latin and colloquial names, it already had a Salish name. What are these names? *(Latin: Lewisia rediviva Colloquial/Common: rock rose or bitterroot Salish: spetlum.)*

   e. What does the Latin name mean? Why was it given this name? *(Lewis is for Meriwether, and rediviva means regrow or resurrect, because it revived and grew after being dried for a year.)*

3. **Watch Section C:** *Botany* (6 minutes)and discuss:

   a. Describe the kinds of habitats in which the bitterroot can be found. *(Mostly arid well-drained sites.)*

   b. What time of year is the bitterroot dug for food? Why? *(When the plant is in the leaf stage, and the roots contain the most nutrients.)*

   c. What is the primary way the plant deals with the cold and dry climate in Montana? *(It is dormant for 10 months of the year.)*

   d. How does the bitterroot spread its seeds? *(By the wind.)*

4. **Watch Section D:** *When We Were Children* (11 minutes) and discuss:

   a. What has happened to many of the bitterroot fields used by the Salish? *(They were plowed up or impacted by grazing, the city of Missoula has been built on them, or they were developed in other ways.)*

   b. The hillside above Missoula (Mt. Sentinel) was once covered with bitterroots. Since there are no buildings or farming there, what do you think happened to the extensive areas of bitterroots? Did you notice what is growing there now? *(Invasive plants such as spotted knapweed and leafy spurge have displaced many native plants)*.

   c. How were the bitterroots preserved? *(They were dried in the sun.)*

   d. What are some of the ways to prepare bitterroots? *(Boiled with venison broth, serviceberries, or huckleberries.)*

   e. What is the importance of the native foods? *(They provided sustenance and were gifts from the creator which were received with thanks.)*

5. **Watch Section E:** *Mr. Bitterroot* (11 minutes) and discuss:

   a. Why did Henry care about the bitterroots? Did he need them for food?

   b. How did Henry get the seeds to germinate?

6. **Watch Section F:** *Gathering* (8 minutes) and discuss:

   a. What is bitterroot gathering like today? Is it a solemn or joyful occasion?

   b. What is the same and what is different from gathering in "the old days"?

7. **Watch Section G:** *The Future* (5 minutes) and discuss:

   a. Did you notice what's taken the place of the bitterroots in Henry's garden? *(Weeds)*

   b. What are school kids in Missoula doing to help our state flower? *(Planting bitterroots in native plant gardens.)*

8. After the end of the film, discuss the following with your students:

    a. Do you like the taste of bitter foods? Can you name some bitter-tasting foods you've eaten? *(You might ask if they have tasted unsweetened chocolate or cocoa powder, and explain that chocolate is bitter until sugar is added.)*

    b. Are there any wild plants that your family gathers to eat?

    c. Why do you think the bitterroot is Montana's state flower?

    d. Can you think of any issues to consider when digging up bitterroot plants now? *(You might discuss possible harm to dwindling populations, private property rights, impacting traditional gathering grounds, helping weeds to invade, etc.)*

    e. How do you think weeds might affect plants like bitterroots? What kind of habitat does the bitterroot usually grow in? Do you know of any non-native, invasive plants (weeds) that grow in that same kind of habitat?

    f. How might the invasion of natural areas by non-native plants affect people like the Native Americans who have a strong cultural tie with the native vegetation?

Now have your students research another Montana plant that was traditionally used for food or medicine. You can have them use one of the resources listed or others you may find, and fill out the activity sheet with their own drawing and information. You may want to have them use the "Questions for Plant Research" as a guide when they research their plant.

Extensions

Have students present what they have learned to other students, parents, or community members.

Put the students' completed activity sheets together as a booklet on native plants for a class resource.

Present ***Lesson 7: Traditional Uses of Native Plants*** in this guide.

Have students try to find food made from native plants in the grocery store.

Have your students taste foods made from local wild plants, such as jams and jellies, which they either made or bought.

Name ____

Montana Natives: People and Plants

Common Name(s): ______________________________

Scientific Name: ______________________________

DRAW YOUR PLANT HERE

Questions for Plant Research

1. How is or was this plant used by Montana native peoples? What parts were used and how were they prepared for use? Did different tribes use it differently?
2. Were there any special ceremonies or rituals observed when gathering, preparing and using this plant?
3. Are there any special legends or traditional stories involved with the use of this plant?
4. How does the plant reproduce? How does it spread into new territory?
5. In what sort of habitat would you look for this plant?
6. Does your plant have any special relationships with other plants or animals? Is it particularly important to certain plants or animals?
7. Is it a rare or threatened species?
8. What other interesting information can you supply about your plant?

LESSON 7

Traditional Uses of Native Plants

Grade level: K-12
Subject Areas: Biology, language arts, visual art, social studies
Duration: 1-2 hours for each activity, plus travel time to field site to collect plants, and preparation time for crafting.
Setting: Field site for gathering plants, any location for crafting (may need access to kitchen, grill, or fire; see procedures).
Season: Fall or Winter to collect plants; anytime for crafting
Conceptual Framework Topic: Ethnobotany

OBJECTIVES

Students will understand that there are many ways in which native plants can be used directly by people today. They will learn at least 2 ways to use native plants themselves. They will consider a variety of topics related to the firsthand use of native plants by people.

METHOD

Students create a craft project, a medicinal salve, and/or a food item from common native Montana plants that are safe for human use.

MATERIALS

(For all 3 activities)

- ✎ Plant identification guide
- ✎ Carving knives (see end of lesson for possible source)
- ✎ Waders (optional)
- ✎ Roasting equipment (fire, oven, or grill)
- ✎ Small pot
- ✎ Beeswax
- ✎ Cheesecloth
- ✎ Olive oil

BACKGROUND

Throughout history, humans have relied on plants for food, medicine, construction and cultural uses. This is still true today. A great number of our medicines, many staple foods (wheat, rice, corn) and material items like clothing and lumber are derived wholly from plants.

In early societies it was impossible to “run to the store” for anything. A bow and arrow for hunting big game, starchy roots for the diet and medicines for managing infection had to be gathered from the landscape. Time of year for harvesting, specific applications, location of resources, how to process and rituals pertaining to some species was information critical to transmit from one generation to the next. Today, we have lost much of this knowledge, even though it was historically present in all cultures.

By engaging students in the study of *ethnobotany* (people & plants), we can rekindle a more fundamental relationship with the landscape.

Contributed by:
David Cronenwett
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Pine Butte Education Program, The Nature Conservancy of Montana

DISCUSSION TOPICS:

How do we live here?: Learning traditional uses of native plants challenges our modern view that natural resources are either completely exploited or completely "preserved"; discussions of sustainable & appropriate use of resources can be readily integrated into lessons. For example: What is sustainable use? Is it different for societies now than in the past? How should natural resources in Montana be used over the short and long term? Do we have an ethical obligation to maintain species diversity, ecological processes and natural beauty? Can we use Nature for our needs without permanently harming it? Is using native/wild plant species for the study of ethnobotany a legitimate use of natural resources today? How might it compare to other resource use in our daily lives?

Cultural/Historical connection: Sampling wild foods, learning about traditional medicinal uses and natural-crafting with plants link students culturally to the past. How did plants help Native & Pioneer peoples deal with medical concerns, potential hunger and material needs? Was it in their best interest to conserve plants in some way? How do you think harvest by Native peoples affected populations of plants?

Living closer to the land: Interacting with nature as an active participant creates an intimacy with the land that cannot be achieved with traditional environmental education. It helps us recognize that humans have a place in the natural environment. How does using plants for various projects make you feel about the species? Does it make you view the landscape differently?

Invasive Species: The problem associated with invasive species becomes more tangible when viewed from an ethnobotany perspective. That is, because weeds threaten the native plant communities that we use for educational purposes, they are a management concern. How do invasive plants affect native plant populations? Do invasives threaten ethnobotany-education?

CONSERVATION, ETHICS & POTENTIAL RISKS

It is important to conserve native plants and habitats. Lessons that focus on gathering must take this into consideration. We should not impair a species' ability to reproduce at particular sites. Plants must occur in healthy abundance if some are to be harvested. If it is possible to harvest a species after it has gone to seed, all the better.

There are no hard and fast rules about gathering wild plants, so a sense of overall ecological health of the species and ecosystem is a prerequisite to heading out into the field. It is a good idea to move around frequently so no single population of plants is too heavily impacted. ***It is important for teachers to closely supervise students' harvesting of plants***, for safety as well as conservation reasons. Any aesthetic impacts of plant harvesting (i.e. digging, cutting, etc.) should be mitigated after gathering takes place.

In this lesson, the cattail doll and toy duck projects are based on Ojibwa designs. Most native peoples in our region used aspen and cottonwood for medicine and material culture. This practice was likely passed on to trappers and settlers of euro-American/euro-Canadian descent. The medicinal salve we make today differs from the past in that we use an olive oil base instead of bear fat.

PROCEDURE

Cattail (*Typha latifolia*), widespread across Montana in wetlands, some riparian areas, and other moist habitats, has many uses.

CAUTION: There are always risks present when using wild plants, particularly for food or medicine. Especially in wetlands, cattails should not be gathered if either Douglas' water hemlock (*Cicuta douglasii*) or poison hemlock (*Conium maculatum*) is nearby. See the *Resources* section of this Guide for identification and resources to learn more about these plants. Although cattails are universally known as a safe food source, teacher discretion is advised.

Food

Cattails are highly edible; in the spring, the new shoots are a delicacy. (Always take care to ***avoid using plants that may have been sprayed with herbicide, or that may be growing in polluted water***.) The golden pollen (late summer) can be made into flour or mixed with wheat flour. Cattail roots contain a significant quantity of starch, a rarity for plants in the Rocky Mountain region. The root is the most calorically valuable part of the plant. The easiest way to consume cattail roots is simply to roast them whole. Find an area where the plants are growing in at least a few inches of water; this operation may require waders. Slowly pull up the desired number of plants and try to preserve the spreading (rhizome) horizontal root stalks. Cut them off near the base of the plant. Rinse any soil from the roots and set them on a bed of glowing coals. Roast for several minutes, turning occasionally. Pull from the fire and let cool. Peeling the outer skin will reveal an inner core of fibers and a white, starchy material. The whole package (minus the skin) is chewed. Swallow the starchy matter, which has a pleasant potato-like flavor, and spit out the stringy fibers.

Source for Scandinavian "Mora" knives and carving tools: **http://www.ragweedforge.com/SwedishKnifeCatalog.html**

Crafting
As a material for natural crafting, cattails are superb. They should be harvested in autumn, when the leaves turn brown. They can be kept indefinitely if dried and stored. To use, soak them in water (warm is better) for an hour or so, until pliable. (They are unusable if green or too brittle) A simple toy duck can be made even by young children. Cattail dolls are generally reserved for older kids and adults. *Please see instructions with illustrations at the end of lesson.*

Cottonwood or Aspen *(Populus spp.)*
Cottonwood (Black, Plains and Narrow-Leaf species) are widely scattered across Montana and strongly associated with streamside, riparian habitats. Aspen are usually found in moist montane forest or montane meadow habitats. The presence of aspen clones indicates water near the surface.

Medicinal Uses
Both aspen and cottonwood contain salicylic acid, which is a pain reliever similar to aspirin. A simple and safe way to use cottonwood medicinally is to make a medicinal salve. Gather some of the buds in late fall or spring. They exude a sticky, yellow-red substance called "balm of Gilead" by herbalists. Be sure not to harvest buds from the tips or "terminal end" of branches since this will inhibit growth of the limb. Gathering from "side branches" is fine, just be sure to move around and not overdo it. You will only need about a handful per ounce of salve to be made.

Put the buds in a small pot and cover them with olive oil. Add a small quantity of beeswax (the ratio of beeswax to olive oil is about 1 to 8) and gently simmer for about 10-15 minutes. Strain with cheesecloth and pour the mixture into a tin like an Altoids® candy container or something similar. Once the salve cools, it can be used on sprains, cuts, etc. It is mildly antiseptic and promotes healing of minor skin injuries. If your finished product is too "thin", reheat and add more beeswax.

Crafting:
The wood of standing dead aspen and to a lesser extent cottonwood is excellent for carving spoons, bowls and other useful implements. The best wood to harvest is upright, without bark and not rotten. Sections of wood at least 2 inches in diameter can be used for spoon carving. Sections about 6 inches in diameter can be split in half and made into bowls by using the burning method. *Please see instructions with photos at the end of lesson.*

How to Make a Cattail Toy Duck

1. Take a well-soaked cattail leaf that is relatively long.

2. Cut off any "woody" sections from the end of the leaf.

3. Tie a simple overhand knot (half-hitch) on the narrow end of the leaf. This forms the head.

4. Make a 90-degree bend about two inches from the head.

5. Begin wrapping the remaining leaf around the base of the neck; this forms the body.

6. Cut off any excess.

7. With a thin strip of cattail tie off the middle of the body.

8. Before long, you'll have many waterfowl in your life! And yes, they float!

Cattail Doll Instructions

1. Begin by wrapping one or two leaves around the fingers to fashion a head.

2. You want to end up with a head that is slightly oval. It should be about 1/7 to 1/8 the height of the finished doll.

3. The head is neatly covered with 3-5 leaves and twisted at the "neck".

4. Tie off the neck with a strip of cattail and set aside.

5. For the arms, you will need 3-4 leaves; the ends should be alternated for consistent thickness. Hold them in a bundle in front of you. Imagine the bundle divided into thirds; at the spot 1/3 from one end of the bundle, begin twisting until the cattails kink.

6. Put the "kink" between your teeth; you will continue twisting the ends as before, but now also wrap both ends clockwise. This will create a rope or cord that will serve as arms for your doll. This cordage technique can be tricky to learn without an instructor.

7. When you have twisted enough cord that equals about half the height of your finished doll, tie it off with a strip of cattail (like you did with the neck earlier). Then begin twisting the other arm just like before.

8. You should end up with two arms that will be approximately the height of your finished doll.

9. Take the arms and insert them in between the leaves of the head & neck.

10. Begin laying leaves over the shoulders. This will create the impression of clothing and give mass to the body. Continue until you feel the body has enough bulk.

11. Take a strip of cattail and tie off at the doll's "waist".

12. With scissors cut off excess leaves. Ending up with a good doll is all about proportion; the head is about 1/8 the length of the body, the arm span should be about the height of the doll.

13. The completed doll (left) and some variations.

Cottonwood or Aspen Crafts

1. Sections of sound (not rotten) dead aspen or cottonwood that are at least 6 inches in diameter can be fashioned into bowls, cups and other containers. Split a "round" of wood in half and place a coal or coals from a fire on top. A straw of some kind will help you focus your breath on the coal, which will begin to burn the wood. After a few minutes of burning, dump the coals back into the fire and use a rock or stick to thoroughly scrape out the cavity. Do not use steel tools for this, as it is unnecessary and will dull them quickly. Once you have burned out the desired amount of wood, do a final scraping and pour some water in the bowl to extinguish any remaining hot spots.

2. Using carving knives, rasps and sandpaper it is possible to create simple, beautiful and functional objects from wood. After a final sanding with a high-grit paper, give your bowl or spoon a few light coats of olive oil to protect them from moisture.

LESSON 8

We Grow Wheat and Eat Tortillas

Grade level: K-4
Subject Areas: Biology, social studies
Duration: 2 class sessions
Setting: Classroom
Season: Any
Conceptual Framework Topics: Importance of agriculture, invasive plant impacts

OBJECTIVES

Students will understand how Montana's primary agricultural crop grows and is made into flour and used in cooking. They will understand that weeds can threaten the production of important crops like wheat.

METHOD

Students observe and journal the process of sprouting a kernel of wheat. They grind wheat and make tortillas from the flour they make.

MATERIALS

- ✎ Stalk of wheat for each student or pair of students (ask a local farmer for some stalks or contact your county extension agent for a source)
- ✎ Jewelry size plastic zip bags, one for each student
- ✎ Yarn for necklaces
- ✎ Journal or notebook (see instructions in ***Lesson 4: Making a kNOweeds Journal*** in this guide)
- ✎ Water crystals (water-absorbing polymers; available through plant and garden supply or craft stores)
- ✎ Food coloring (optional)
- ✎ Wheat grinder or food processor
- ✎ Enough wheat to have 1-½ cups flour for each group of 4 students
- ✎ Recipe and ingredients for tortillas (see end of lesson)
- ✎ Plastic bags
- ✎ Skillet and heat source for cooking tortillas

BACKGROUND

As of 2009, approximately 60 million acres of Montana's 93 million acres are used for farm and ranch production. Most of this land is rangeland used for cattle and sheep, with about 17.5 million acres used for growing crops. The average size of a farm in Montana is 2,120 acres. Additionally, some government land is leased for agricultural purposes. About five percent of the population in Montana are farmers and ranchers, and a total of 17 percent of the population hold agriculture-related jobs.

Agriculture contributes more than $2.4 billion to the state's economy annually. Montana's primary crop is wheat. Other crops grown in Montana include barley, oats, berries, cherries, corn, hay, mint, sugar beets, sunflowers, apples, canola, potatoes, dry beans, field peas, flax, grapes, garlic, lentils, safflowers, mustard,

(Adapted from *Agriculture in Montana Schools* Curriculum) squash, alfalfa, and many more. Montana wheat is used as livestock feed or made into flour for foods like bread, cakes, cookies, crackers, and pretzels. Our wheat is also used for non-food items such as glue and pharmaceuticals.

In August or September, the farmer combines or harvests the wheat. Next, the wheat is sold to various industries, which make food or feed, or for shipment overseas. The wheat is put through a cleaning process to remove foreign matter (weed seeds, corn seeds, beans, stems). Rollers then press over the wheat kernels to break them into pieces, and they are shaken on screens to sift out the bran (the broken coat of the kernel) and germ (the part of wheat used to grow a new plant) not used in wheat flour. If whole wheat bread is what the mill wants to make, the bran and germ are added back in. (Information from the Agriculture in Montana Schools website: http://aginmtschools.org/).

Invasive plants are a major problem for Montana's growers. Invasive plants reduce crop production and are expensive and time-consuming to control. Montana farmers and ranchers spend $100 million each year trying to control invasive plants. For example, farmers and ranchers applied 4,737,000 pounds of chemical herbicides to wheat crops alone in Montana in 2008. Unfortunately, this expensive effort isn't entirely successful, due to the tenacious characteristics of invasive plants.

PROCEDURE

1. Ask your students if they know what Montana's biggest business is in economic terms. Explain that it is agriculture, or farming and ranching. Ask how many different agricultural products (crops and livestock) they can list that are grown in Montana. Explain that wheat is the primary crop grown in Montana.

Give each student a stalk of wheat. Have children break off the stem. Explain that the stem is a straw. Have children take turns rolling the head in their hands. Separate the wheat kernel from the chaff. Estimate how many kernels most heads have. Count the kernels and compare to their estimates. Explain that what the children just did (separating the kernel from the chaff) is the job a combine on the farm does.

2. Make sprouting bags. You can squirt several drops of food coloring into a pint of water. Each child receives one kernel of wheat, 3 or 4 water crystals, 1 small jewelry size plastic zip bag (with hole punched above the seal) and 3 or 4 drops of colored water. Put all items into the bag, zip the bag shut and thread yarn through to make a necklace. The necklace could be worn every day throughout the week. **They should be left at school.** Begin this activity on Monday to be able to journal throughout the week.

3. Use your kNOweeds Journals or other student journal or notebook. Each day of the week observe, discuss, and journal by drawing or writing a few words. By the end of the week the kernel should have roots and a green sprout. Send it home at the end of the week to plant or plant it in a small pot with potting soil in the classroom.

4. While you are sprouting the wheat or after it sprouts, make the tortillas using the recipe at the end of the lesson.

5. Talk about how weeds can threaten the growth of plants, including important plants that provide us with a lot of our food.

6. Make a copy of the tortilla recipe in the tortilla shape for each student and have them cut out the recipe circle to take home.

Extensions

Follow up with lessons on plant competition and weeds in this guide.

Make Tortillas in a Bag

FLOUR TORTILLAS IN A BAG

1-½ cups all-purpose flour

1 teaspoon salt

½ teaspoon baking powder

3 tablespoons shortening

½ cup hot water (125-130°F)

In a large plastic bag combine flour, salt, and baking powder. Close bag and shake to mix.

To the ingredients in the bag, add the shortening. Close bag with twist tie and work mixture with fingers until no large lumps of shortening remain.

Add the hot water to the bag. Close the bag and mix with fingers until the ingredients form soft dough that pulls away from the sides of the bag.

Turn the dough out onto a lightly floured surface. Divide dough into 4 equal pieces and shape into balls. Each child receives two balls. Cover them with the plastic bag, and let rest for 15 minutes.

Roll or pat the dough into 8-inch to 10-inch circles. Place each circle on a griddle or frying pan, heated to medium high. Cook until dark brown spots appear. Turn tortilla and cook on the other side until brown.

Ways to Enjoy:

Roll up a tortilla with cheese, salsa and refried beans.

To make a fun dessert, sprinkle with cinnamon and sugar on top roll up and eat.

LESSON 9

Local Color: Dyeing With Plants

Grade level: 6-12
Subject Areas: Biology, chemistry, art, history
Duration: 3-4 class periods
Setting: Classroom/lab, field site for plant collecting
Season: Spring, Summer or Fall (anytime if plants are collected ahead of time)
Conceptual Framework Topics: Humans and plants, ethnobotany

OBJECTIVES

Students will learn about ethnobotany by exploring ways Native Americans and Europeans utilized plants, practice plant identification skills; and extract and use plant dyes from hand-collected, locally growing material.

METHOD

Students discuss the importance of plants in historical and modern settings. A hands-on activity helps students to identify, collect, and extract dye from locally growing plants to naturally dye a final product. Select plant identification skills are cemented when students determine and draw the key distinguishing features of their local plant of choice.

MATERIALS

- ✎ **Local Dye Plants** information sheet
- ✎ Plant identification guides
- ✎ Drawing/coloring utensils and white paper
- ✎ A few each of: spades, trowels, clippers
- ✎ Used grocery bags
- ✎ Plain white T-shirts (either students' old shirts or ones newly purchased) or other fabric (you may want to have students experiment with different types of materials)
- ✎ Mortars and pestles, blender, or other implements for crushing or grinding plants
- ✎ Paintbrushes (optional)
- ✎ If boiling and steeping plant material: hot plates, steel pots, cheesecloth, rubber bands, ladles or large slotted spoons to scoop hot materials out of water
- ✎ Latex gloves to protect hands from possibly allergenic plants
- ✎ Alum (aluminum potassium sulfate) found in spice section of grocery stores or drugstores (optional)

BACKGROUND

The study of how humans relate to plants is *ethnobotany*. Past and present uses of plants in Montana include food, shelter, medicine, fuel, clothing, and ornamentation.

People have been creating dyes to color clothing for thousands of years. The earliest written record for dyeing dates back to 2600 B.C. Before people learned how to make dyes from chemicals, plants were used to create dyes (along with minerals and animal substances). It was a very difficult process to extract enough dye to color whole pieces of clothing. It was even more difficult to make the dye permanent, to prevent it from washing out when the clothing was washed. This was accomplished by using a mordant (substance for colorfastness) of various forms. Consequently, in the early days of dyeing cloth, often only royalty and the very wealthy could afford it. As dyeing became more common and more could afford it, certain colors (usually purple or blue) became reserved for royalty. Records show that dyeing was practiced by many different cultures all over the world. Prior to the European migration to the Americas, Native Americans had been dyeing their fabrics for many years. When Europeans settled in the Americas, they learned some of the native dye plants, and they brought with them many plants known for their good dyeing properties. Some of these plants are considered weeds in the Americas today. For example, the Puritans brought dandelions to the colonies in the 17th century, using the plants to obtain yellow color from the flowers and magenta from the roots.

Dyes are organic compounds that selectively absorb some colors (visible wavelengths) and reflect others. Different dyes are soluble in different liquids (water, alcohol, etc.). Most dye molecules have at least 3 types of chemical groups which contribute to their properties. The *chromophore* produces the color, the *auxochrome* controls the intensity of the dye and the chemical bonding to the fabric, and the *solubolizing group* allows it to disolve in a liquid.

In the dye bath the dye molecule may be neutral or ionize. Although the dye fragment may be either a cation or anion, most natural dyes are anionic. These are also known as acid dyes because they work best in slightly acidic baths. The anionic dye forms a strong bond with a fabric that has a cationic bonding site. For more information on the chemistry of plant dyes, see the ***Resources*** section of this guide.

PROCEDURE

1. Have a class discussion about the importance of plants in our everyday lives. Ask students to list items they use during the day that come from plants. Discuss the different uses of plants in the past and present. Lead a discussion on why early Montanans, Native and European, used dyes from plants. Why couldn't they just buy dyes? How did imported goods and new technology change that? Do people still use plant dyes today? Discuss present craft traditions of hand dyeing for artistic yarns, cloth, and other items as a legacy of early people influencing our culture. Have students predict what it is like to use plant dyes – how long does it take to dye cloth, how many steps are there, how difficult is it? Discuss throughout the lesson the chemistry of dyeing.

Dyeing Activity

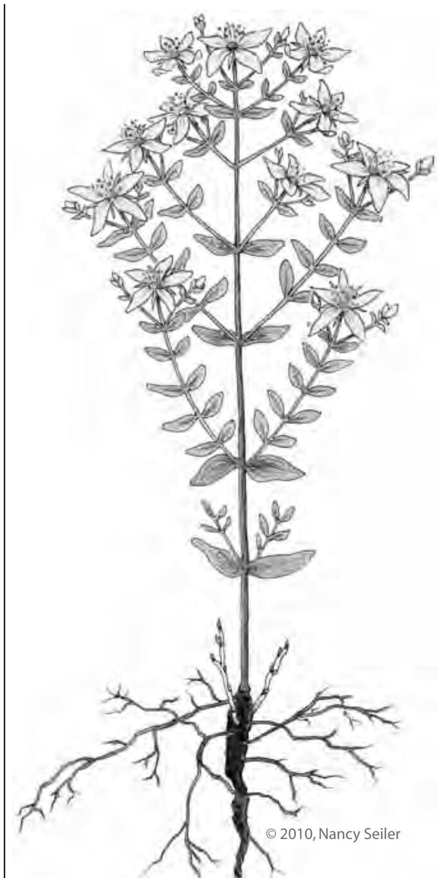
2. Prior to conducting this activity, educators should acquaint themselves with dye plants (listed in Local Dye Plants sheet) growing locally, possible field trip locations for collecting those plants, and what stage of growth plants are in at the time. (Alternatively, the teacher could collect plants in spring or fall for use at a later time in the school year when plants may not be accessible.) You should also determine the amount of time available for this activity and the desired results. Some dyeing procedures require lengthy steeping times, while simple crushing of berries and flowers can be done much more quickly, although with lower quality results.

3. Have students select from the list of available local plants the species of his/her choice. Because native plants are important components of healthy functioning ecosystems, students should either select non-native plants or very abundant and widespread natives. When native species are used, harvest no more than 5% of the total population. The student should then determine what the key diagnostic features are for his/her chosen plant and draw a replica of the plant to later aid the student in field identification.

4. Take students on a field trip to a pre-determined destination where all chosen plant species can be collected. Students must use their drawings and field plant identification guides to identify their chosen plant species. Using trowels, spades, clippers and used grocery bags, have students collect their chosen plants, making sure that key plant parts are properly collected. The amount needed will vary depending on the amount and type of material to be dyed, the intensity of the dye, and the type of plant used. In general, 2-3 pounds of plant material will make about 4 gallons of dyebath.

5. Once back in the classroom, if you wish to apply a mordant such as alum to the material to make it colorfast, complete the following (you may want to do this step as the plant dyes are steeping):

- Using a stainless steel pot, dissolve 5- ½ oz. of alum in 4 gallons of lukewarm water. Wet the material you wish to dye and then immerse it in this mixture with a wooden spoon. Bring it slowly to a boil for 20 minutes.
- Remove it from the mordant bath, wring it out and place it in the prepared dyebath or paint with dye. Alternatively, you can add plant material and water to mordanted water.



St. Johnswort
Hypericum perforatum

Extensions
Learn about different materials Native Americans and Europeans used for clothing and experiment dyeing samples of each of these.

Try dyeing cornhusk dolls or homemade paper.

Experiment with different techniques of dyeing, looking at the importance of each of the following on how well or how long the fabric holds the dye: mordant versus no mordant, type of fiber, temperature, time, freshness of the plant material.

6. To prepare the dyebath, select the appropriate procedure below.

- If extracting dye using simple crushing and painting: Lay T-shirts out on open surfaces and have students crush a variety of the collected parts (berries, flowers, and leaves) with mortars and pestles. Using paintbrushes, students can paint the scene of their choice on their white T-shirt canvas. Allow to dry for 24 hours.
- If extracting dyes via a steeping procedure: Set steel pots on hot plates as students are rinsing plants under running water. Crush, grind, or tear plant parts up as much as possible, using a mortar and pestle or blender. Wrap needed plant parts in cheese cloth, fasten with rubber bands, and place in pots, covering the bundle with water. Apply heat 30-60 minutes or until a heavy concentration of dye has been released to color the water. The steeping time will vary depending on the desired color and chosen plant part. While plants are steeping, have students prepare mordant or take notes on the process they are following. Alternatively, split this part of the activity into two sessions, steep plants overnight, and proceed to the next step the following day.

7. When steeping of the plant material is finished, add hot water to make up to 4 gallons of dye. At this point you can remove the cheese cloth and dye materials.

8. Add fiber or mordanted fiber to be dyed to pot and continue to boil, stirring occasionally to even out the color. Check for depth of fiber color by lifting it up with a wooden spoon. Dry fiber will be lighter in color than when wet. Try adding another teaspoon of mordant if the color is weak.

9. When the desired color is reached or after one hour, take pot off the boil and set aside to cool. When water is cool, remove the dyed fibers from the pot. Wearing latex gloves, wring the dye water from the fiber back into the pot or into a sink.

10. Rinse loose dye and plant fibers from the dyed fiber with clean water under a faucet at room temperature.

11. Hang dyed fiber to dry. *NOTE: When sending material home with students, if mordant was not used, it is important to send a note home with students, warning against the washing of the dyed shirts with other clothing as the hand-extracted dye will bleed.*

12. At the end of the project, have them discuss their predictions, results, problems and successes. Have them think about and discuss why some fiber artists and fiber wearers today might prefer natural dyes.

LOCAL DYE PLANT INFORMATION

Common Name	Scientific Name	Parts Used	Preparation	Colors	Native Status
Black cottonwood	*Populus trichocarpa*	Buds or fruits	Boil	Buds: yellow Fruits: red, green, yellow, purple	Native
Blueberry/ huckleberry/cranberry	*Vaccinium spp.*	Berries	Crushed, mixed with water, or boiled	Navy blue	Native
Bush cranberries	*Viburnum spp.*	Berries	Crushed, mixed with water, or boiled	Red-pink	Native
Common sunflower	*Helianthus annuus*	Flowers or seeds	Flowers: crushed or boiled Seeds: boiled	Flowers: yellow Seeds: black or purple	Native
Oregon grape	*Mahonia repens*	Shredded bark	Boil	Brilliant yellow	Native
Elderberries	*Sambuscus spp.*	Berries	Crushed, mixed with water, or boiled	Crimson, lavender or violet	Native
Goldenrod	*Solidago spp.*	Flowers	Crushed or boiled	Yellow	Native
Alder	*Alnus spp.*	Bark and twigs	Boil	Red-brown or orange	Native
Green rabbitbrush	*Chrysothamnus viscidiflorus*	Mature flowers, buds, twigs	Boil for several hours	Flowers: lemon yellow Buds and twigs: yellow-green	Native
Juniper	*Juniperus spp.*	Bark, berries, needles	Boil	Brown	Native
Mountain hemlock	*Tsuga mertensiana*	Inner bark	Boil	Red-brown	Native
Skunkbush sumac	*Rhus trilobata*	Leaves	Boil	Black	Native
Narrow-leaved yucca	*Yucca glauca*	Leaves	Boil	Red	Native
Stinging nettle	*Urtica dioica*	Roots	Boil	Yellow	Native
Strawberry blite	*Chenopodium capitatum*	Flower clusters	Crushed, mixed with water, or boiled	Maroon	Native
Western gromwell	*Lithospermum ruderale*	Roots	Boil	Red	Native
Western hemlock	*Tsuga heterophylla*	Inner bark	Boil	Red-brown	Native
Western serviceberry	*Amelanchier alnifolia*	Berries	Crushed, mixed with water, or boiled	Purple	Native
Witch's hair lichen	*Alectoria spp.*	All	Boil	Yellow	Native
Yarrow	*Achillea millefolium*	Flowers	Crush and boil	Light green	Native
Common mullein	*Verbascum thapsus*	Flowers	Crushed or boiled	Light yellow	Introduced
Dalmatian toadflax	*Linaria vulgaris*	Flowers	Crushed, mixed with water, or boiled	Yellow	Introduced
Dandelion	*Taraxacum officinale*	Flowers or roots	Flowers: crushed or boiled Roots: boiled	Flowers: yellow Roots: magenta	Native and Introduced
Dyer's woad	*Isatis tinctoria*	Leaves	Boil	Blue	Introduced
Purple loosestrife	*Lythrum salicaria*	Flowers	Crushed or boiled	Purple or lavender	Introduced
St. Johnswort	*Hypericum perforatum*	Flowers or stems	Flowers: crushed or boiled Stems: boiled	Flowers: yellow or orange-red depending on mordant Stems: brown red if alum mordant	Introduced
Tansy ragwort	*Senecio jacobaea*	Flowers or leaves	Crushed or boiled	Flowers: yellow Leaves: green	Introduced
Yellow flag iris	*Iris pseudacorus*	Flowers or roots	Flowers: crushed or boiled	Roots: boiled Flowers: yellow Roots: brown or black	Introduced
Yellow starthistle	*Centaurea solstitialis*	Flowers	Crushed or boiled	Yellow	Introduced
Yellow toadflax	*Linaria dalmatica*	Flowers	Crushed, mixed with water, or boiled	Yellow	Introduced

LESSON 10

Know Your Neighbors

Grade level: K-8
Subject Areas: Biology, language arts, visual arts
Duration: Two 30-minute sessions on different days, plus travel time to field site for first session
Setting: Field site where native and non-native invasive plants can be found and classroom
Season: Spring, Summer, Fall
Conceptual Framework Topics: Species, classification, identification

OBJECTIVES

Students will learn how to collect and preserve plants, and understand why plants are collected. They will understand how to carefully collect so as not to harm desirable species that are uncommon. Students will learn about native and non-native plants in their area and will be able to identify at least 2 common native plants and 2 common local weeds.

METHOD

Students visit outdoor sites to examine different species of native plants and non-native, invasive species. They create their own mini weed I.D. booklet by collecting and pressing samples of weed species, writing their own descriptions of what the plant looks like and where it grows, and sketching (or alternatively, for younger students, coloring in) details of it. They put it all together in the classroom after their pressed samples are ready.

MATERIALS

- ✎ Plant presses (See **Making Plant Presses** procedure included in this lesson)
- ✎ Hand lenses (enough for each student or to share)
- ✎ Scissors and small spades (a few to share)
- ✎ **Plant I.D. Activity Sheet** (optional) may be especially helpful for younger students; provide enough for each student. You may want to copy this onto cardstock to make a more durable sheet.
- ✎ Coloring sheets for selected plants (make copies of the plant drawings provided with this guide or find wildflower and weed coloring pages in the U.S. Forest Service *Celebrating Wildflowers Coloring Page* at **http://www.fs.fed.us/wildflowers/kids/coloring/index.shtml**
- ✎ Notebook or clipboard for writing on (a stiff piece of cardboard with a binder clip can serve as a clipboard)

BACKGROUND

Scientists often use samples of real plants to help them and others identify and learn more about plants. Such samples are stored in herbariums (plant collections) or used in educational materials such as posters or displays. Identifying plant species and understanding something about the kind of environment a plant lives in is an essential first step in understanding the ecology of the plant community around you and the effects of invasive species.

Montana has a wide variety of native *flora*, or plant life, ranging from those in the moist, old forests in the northwestern part of the state to the dry prairie grasslands in the east. (For more information on plants of Montana, visit http://montana.plant-life.org/index.html). Montana also has 34 plant species listed as noxious weeds. There are other species that show invasive tendencies, but have not yet colonized sites in Montana. Recognizing local, common native plants and invasive non-natives is a first step in understanding the ecology of the landscape and the challenges faced in managing invasive weeds.

PROCEDURE

1. Ahead of Time: Use ***Lesson 13: Weed By Any Other Name...*** in this guide or another lesson that teaches students what terms such as *weeds, native, noxious* and *invasive* mean. Scout ahead to find a field trip site where you can find some native plant species and some invasive weeds. This may be as convenient as your schoolyard or a nearby park or empty lot. Make sure it is a site where your students can each take a sample of a native plant (leaves, stem, and maybe flower) without doing significant harm to the plant population. A good rule of thumb is to collect one plant only when there are at least 20 other individuals of that species in the vicinity.

2. Visit the site with your students. See how many plants your students can identify by name and whether they are native, non-native and/or invasive weeds. If they need help, have them use a plant guide book or weed identification materials (see ***Resources*** section of this guide for ideas).

3. Explain that scientists often use samples of real plants to help them and others identify and learn more about plants. They must carefully collect and dry the plants for later use. Tell your students that is what they are going to do today, and that they will be making their own class identification book of native plants and invasive non-native plants (weeds) in your area. Before they start collecting, ask if they can think of some basic "rules" they should consider when collecting plants. *If they need assistance, help them to come up with these:*

- *Collect only native plants for which there are at least 20 of the same kind at the site for each one you collect.*
- *Do not collect plants if they might be rare or endangered, even if they are abundant at your site.*
- *Collect only as much as you need.*
- *Collect plants only where you have permission.*
- *In the case of "weeds," be careful not to allow any seeds or roots to fall outside of the collecting area.*

4. Have each student collect 1-2 native plants and 1-2 invasive weeds. The easiest way to do this, with minimal disturbance to the site, is to have them cut off the plant or part of the plant with scissors. Alternatively, they can dig up the roots as well. Depending on the plant, these may not fit into the press and if they are very "fleshy" they may be difficult to press. But they may want to dig up a few different types to see how the root systems may differ.

5. Have them place the plant between the sheets of paper in the press and arrange it so representative parts can best be seen. Make sure each student's name is on their press, if they each have one, or on a piece of paper placed next to the plant, if they are sharing presses. Make sure each specimen is separated from others by several pages of paper.

6. Now using either the **Plant I.D. Activity Sheet** or plain paper for the "field draft," have students make a written description of their plant, note the kind of habitat it is growing in (you may ask them to include things like surrounding vegetation, soil conditions such as dry or marshy, etc.), note any interesting facts they can find, and any information they can find about methods to control it (for invasive weeds), as well as its name (scientific and common), and date and location collected. You may also want to have them draw details of the flower or leaves, or color a copy of the plant from the plant drawings provided in this guide.

Drying in the presses may take 3-5 days.

Plants that are moist may need to have the paper changed each day. Before mounting, the plant must be completely dry (to prevent mold).

When the plant specimens are ready, they can be mounted on the Activity Sheet using glue or tape, or clear contact paper.

All the class sheets and specimen information can be put together into a binder to make an I.D. guide to common local native plants and weeds.

Extensions

Have students present what they have learned to other students, parents, or community members.

Students request that their I.D. book be placed on public display in a community area such as a local museum, visitors' center, ranger station, or at a local business.

Making Plant Presses

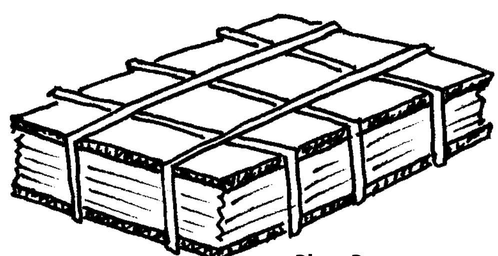
A plant press is a device that places fresh plant specimens between absorbent material, such as paper, and applies pressure to hasten the drying process. There are many variations of designs for plant presses, and many are available to buy. For classroom use, you can make simple presses out of paper, cardboard, and rubber bands or weights. For more durable and efficient presses, plywood or other board covers can be used.

Materials for each press

- 6" x 8" (or larger depending on size of plants to press) sheets of butcher or craft paper
- Sheets of newspaper cut into those same dimensions
- 2 sheets of sturdy corrugated cardboard cut into the same dimensions
- Thick rubber bands long enough to stretch around the width of the press—enough to place one band about every 2 inches
- Optional: 2 pieces of ¼" plywood or pegboard

Place layers in the following sequence:

(Optional board)
One piece of cardboard
4 sheets of newspaper
1 sheet of craft paper
Plant specimen
1 sheet of craft paper
4 sheets of newspaper
One piece of cardboard
(Optional board)



Plant Press

If you want to press more than one specimen per press, simply repeat the newspaper-to-newspaper sequence for not more than five specimens. Very fleshy (thick) or moist specimens should have a cardboard layer between them as well. Longer plants may be bent to fit into the press.

Place rubber bands around the press and/or place the press under a slightly larger, fairly heavy book. For moist specimens, such as fleshy plants or those collected in the spring or early summer, the paper surrounding them may need to be changed every day as it absorbs moisture. Plants may take 3-5 days to dry.

Name ______________________________

Plant I.D. Activity Sheet

Plant Name: ______________________________

Collected by: ______________________________

Location Collected: ______________________________ Date Collected: ______________

Status (circle all that apply): Native Non-native Invasive Noxious

Tape or glue your
pressed specimen here

Description:

Habitat:

Interesting Information:

Control Methods (for "weeds"):

Detail drawing:

LESSON 10

Know Your Neighbors

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METHOD

Students visit outdoor sites to examine different species of native plants and non-native, invasive species. They create their own mini weed I.D. booklet by collecting and pressing samples of weed species, writing their own descriptions of what the plant looks like and where it grows, and sketching (or alternatively, for younger students, coloring in) details of it. They put it all together in the classroom after their pressed samples are ready.

MATERIALS

- ✎ Plant presses (See **Making Plant Presses** procedure included in this lesson)
- ✎ Hand lenses (enough for each student or to share)
- ✎ Scissors and small spades (a few to share)
- ✎ **Plant I.D. Activity Sheet** (optional) may be especially helpful for younger students; provide enough for each student. You may want to copy this onto cardstock to make a more durable sheet.
- ✎ Coloring sheets for selected plants (make copies of the plant drawings provided with this guide or find wildflower and weed coloring pages in the U.S. Forest Service *Celebrating Wildflowers Coloring Page* at **http://www.fs.fed.us/wildflowers/kids/coloring/index.shtml**
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2. Visit the site with your students. See how many plants your students can identify by name and whether they are native, non-native and/or invasive weeds. If they need help, have them use a plant guide book or weed identification materials (see ***Resources*** section of this guide for ideas).

3. Explain that scientists often use samples of real plants to help them and others identify and learn more about plants. They must carefully collect and dry the plants for later use. Tell your students that is what they are going to do today, and that they will be making their own class identification book of native plants and invasive non-native plants (weeds) in your area. Before they start collecting, ask if they can think of some basic "rules" they should consider when collecting plants. *If they need assistance, help them to come up with these:*

- *Collect only native plants for which there are at least 20 of the same kind at the site for each one you collect.*
- *Do not collect plants if they might be rare or endangered, even if they are abundant at your site.*
- *Collect only as much as you need.*
- *Collect plants only where you have permission.*
- *In the case of "weeds," be careful not to allow any seeds or roots to fall outside of the collecting area.*

4. Have each student collect 1-2 native plants and 1-2 invasive weeds. The easiest way to do this, with minimal disturbance to the site, is to have them cut off the plant or part of the plant with scissors. Alternatively, they can dig up the roots as well. Depending on the plant, these may not fit into the press and if they are very "fleshy" they may be difficult to press. But they may want to dig up a few different types to see how the root systems may differ.

5. Have them place the plant between the sheets of paper in the press and arrange it so representative parts can best be seen. Make sure each student's name is on their press, if they each have one, or on a piece of paper placed next to the plant, if they are sharing presses. Make sure each specimen is separated from others by several pages of paper.

6. Now using either the **Plant I.D. Activity Sheet** or plain paper for the "field draft," have students make a written description of their plant, note the kind of habitat it is growing in (you may ask them to include things like surrounding vegetation, soil conditions such as dry or marshy, etc.), note any interesting facts they can find, and any information they can find about methods to control it (for invasive weeds), as well as its name (scientific and common), and date and location collected. You may also want to have them draw details of the flower or leaves, or color a copy of the plant from the plant drawings provided in this guide.

Drying in the presses may take 3-5 days.

Plants that are moist may need to have the paper changed each day. Before mounting, the plant must be completely dry (to prevent mold).

When the plant specimens are ready, they can be mounted on the Activity Sheet using glue or tape, or clear contact paper.

All the class sheets and specimen information can be put together into a binder to make an I.D. guide to common local native plants and weeds.

Extensions

Have students present what they have learned to other students, parents, or community members.

Students request that their I.D. book be placed on public display in a community area such as a local museum, visitors' center, ranger station, or at a local business.

Making Plant Presses

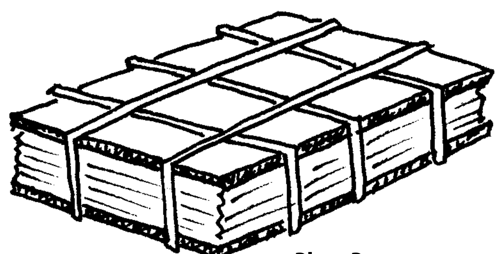
A plant press is a device that places fresh plant specimens between absorbent material, such as paper, and applies pressure to hasten the drying process. There are many variations of designs for plant presses, and many are available to buy. For classroom use, you can make simple presses out of paper, cardboard, and rubber bands or weights. For more durable and efficient presses, plywood or other board covers can be used.

Materials for each press

- 6" x 8" (or larger depending on size of plants to press) sheets of butcher or craft paper
- Sheets of newspaper cut into those same dimensions
- 2 sheets of sturdy corrugated cardboard cut into the same dimensions
- Thick rubber bands long enough to stretch around the width of the press—enough to place one band about every 2 inches
- Optional: 2 pieces of ¼" plywood or pegboard

Place layers in the following sequence:

(Optional board)
One piece of cardboard
4 sheets of newspaper
1 sheet of craft paper
Plant specimen
1 sheet of craft paper
4 sheets of newspaper
One piece of cardboard
(Optional board)



Plant Press

If you want to press more than one specimen per press, simply repeat the newspaper-to-newspaper sequence for not more than five specimens. Very fleshy (thick) or moist specimens should have a cardboard layer between them as well. Longer plants may be bent to fit into the press.

Place rubber bands around the press and/or place the press under a slightly larger, fairly heavy book. For moist specimens, such as fleshy plants or those collected in the spring or early summer, the paper surrounding them may need to be changed every day as it absorbs moisture. Plants may take 3-5 days to dry.

Name ______________________________

Plant I.D. Activity Sheet

Plant Name: ______________________________

Collected by: ______________________________

Location Collected: ______________________ Date Collected: ____________

Status (circle all that apply): Native Non-native Invasive Noxious

Description:

Habitat:

Interesting Information:

Control Methods (for "weeds"):

Detail drawing:

Tape or glue your
pressed specimen here

LESSON 11

Who Lives Here? Plants as Environments

OBJECTIVES

Students will understand that plants provide habitat for animals. Different types of plants provide living conditions for different animals, which may in turn influence other species living in the same area. Changes in vegetation may have cascading effects on animals living in an area as the components of an ecological web.

METHOD

Using equipment made with common, easily-obtainable materials, students collect invertebrates living on local plants. They sort and count the different types they find, and compare *assemblages* of invertebrates on different plant species. Students create an ecological web based on their findings and discuss how changes in vegetation due to plant invasions might have cascading effects on an area.

MATERIALS

- ✎ Insect collecting equipment (any or all of the following):
  - "Shake-it" containers (see attached instructions for making your own) OR a flat white cloth such as a pillowcase or part of a sheet
  - Sweep nets (make your own using the attached instructions or order from a biological supply company).
  - Small jars, Ziploc® plastic bags, or other suitable containers to temporarily hold invertebrates
- ✎ Hand lenses (enough for each student or to share)
- ✎ Invertebrate identification guides (*Golden* makes easy-to-use and inexpensive guides)

BACKGROUND

Plants serve many ecological functions, including providing habitat for animals. Important but often overlooked animals include invertebrates, which live almost everywhere and play huge roles in the ecological web of life. Invertebrates living on plants may eat plants, parasitize plants, eat others that eat the plants, or pollinate plants, as well as serving as food for reptiles, amphibians, birds and mammals.

The number of different kinds of organisms living in an area is one measure of its *biodiversity*. Generally, the more complex a plant community, the more biological niches available for other organisms, and the greater the biodiversity. Invasive plants may affect which invertebrates live in an area and in turn have cascading effects on other organisms.

Grade level: K-8
Subject Areas: Biology
Duration: One 60-minute session or two 30-minute sessions, plus travel time to field site if necessary
Setting: Classroom and field site with some variety of plant species; this could be in or near your schoolyard.
Season: Spring, Summer, Fall
Conceptual Framework Topics: Organisms and environments, interdependence, populations, habitats, classification, biodiversity

PROCEDURE

1. **Ahead of Time**
Make "Shake-it" collecting containers or sweep nets, or gather white sheets of cloth about the size of a pillowcase. NOTE: Check with students and parents to determine if any students have known allergies to insect bites or stings. You may need to have these students only handle insects in safe, closed containers such as jars or thick bags.

2. Choose the location(s) for your study. Areas with shrubs, bushes or small trees will best be sampled using shake-it boxes or sheets. Areas with grass or small plants will best be sampled with sweep nets. For a more interesting study, you may want to have students compare invertebrates found on different types of plants or in different environments.

3. At your site with your students, tell them that you will be sampling an area to see how many invertebrates live on the plants there. Discuss or review with students what invertebrates are. Ask them how many different kinds they think they might find. Have them predict which kinds of plants or areas will have them most kinds of invertebrates.

4. To collect invertebrates from bushes or small trees, place a piece of white cloth under a plant and shake it to dislodge insects. Transfer invertebrates to jars to examine them. Or use a shaker box. To use, hold the open end of the box under a plant and shake the plant (obviously this will work better for shrubs or large plants such as balsamroot). Tip the box to let insects slide down into the bag. Invertebrates can be examined in the bag or transferred to small collecting jars.

5. To sample using a sweep net, first make certain that the net is assembled and ready to use. If using a homemade net, bend your coat hanger circle so that there is a flat side to your sweep net. A good shape is a triangle with the handle extending from one of the points.

6. Have students practice making a back and forth "figure 8" swing in such a way that the opening of the net is always first to sweep the area.

7. Pick an area as a "practice" site and practice sweep net swings with students. Have each student go back and forth over the area using the "figure 8" motion until a student has swept about a square meter area.

8. Immediately grasp the net about half way up to make sure your captured animals do not escape.

9. While another student holds a Ziploc® bag open, place the net over it, loosen your grasp and turn it inside out into the bag. Carefully shake and remove the net from the bag, making certain to seal it so the animals do not escape.

10. Once you have captured the organisms, you can observe them through the jar or bag and try to: identify their species, family and/or class, or simply sort them into types so that you can see how many different kinds you have found.

11. Explain to your students that this variety of animals is one type of *biodiversity*, the range of different kinds of living things in an area. Discuss whether they think they have found more or less diversity than they expected.

12. Once you have gathered all of the necessary information, release your animals back into the area(s) where you originally captured them.

13. Back in the classroom have your students make an ecological web of all the organisms in the area they can think of that are interdependent, starting with the plants and invertebrates you sampled.

14. Discuss with your students how they think changes in the plant community, such as a weed invasion, might change the invertebrates they would find and the rest of their ecological web.

Extensions

Design and conduct an experiment to compare the number and diversity of invertebrates living in native vegetation to sites with a lot of invasive species.

Making Shaker Boxes and Sweep Nets for Collecting Invertebrates

MAKING SHAKER BOXES:

A shaker box is a tool for easily collecting the invertebrate animals living on plants, many of which would not be seen even in a fairly close inspection of a plant. These are very inexpensive to make and easy to use.

Materials for each box:

- ✎ Shallow cardboard box: a file folder box, an 8.5"x11" paper ream box, or a file box top all work well. Any box about 8" wide and 2" to 4" inches deep will work.
- ✎ 1 sheet of white paper (optional)
- ✎ 1 gallon plastic Ziploc® bag or supermarket produce bag
- ✎ Two 1" binder clips, OR tape, OR stapler
- ✎ Scissors

Using the box

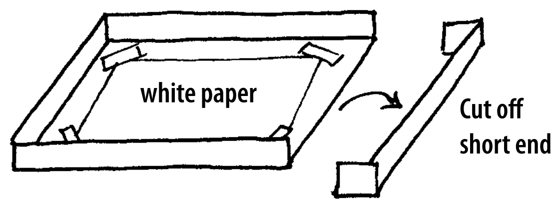
Hold the box under a leafy branch and shake the branch.

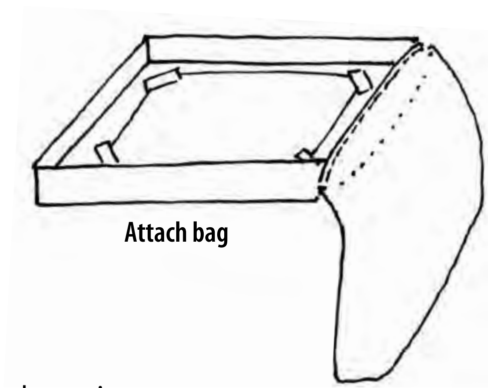
When an invertebrate falls into the box lid, tip the lid so that the invertebrate slides into the bag.

Scoop the invertebrate out into a container or keep in it the bag for observation.

Instructions:

- Cut one short end of the box off
- Unless the box is white and smooth inside, tape white paper to the inside bottom of the box
- Place the cut end of the box inside the mouth of the plastic bag so the box contents would empty into the bag
- Tape, staple or clip the bag onto the box

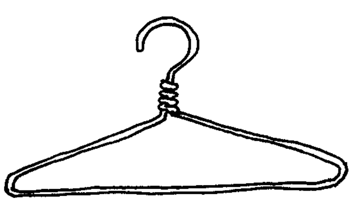




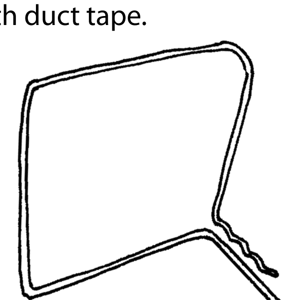
Attach bag

MAKING SWEEP NETS:

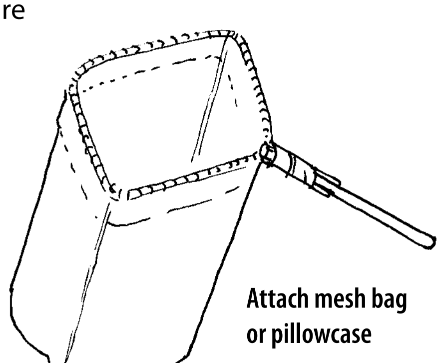
You can purchase very inexpensive mesh bags that are used as paint strainers in a hardware or paint store. A pillowcase may also be used. The top (opening) of a bag can then be sewn or even stapled onto a stiff wire (coat hangers work well for this) bent into a circle with the ends of the wires stretched out together. These ends can be fastened to a wooden handle (a dowel or rake handle) with duct tape.



Start with coat hanger



Unwind hanger



Attach mesh bag or pillowcase

INTRODUCING INVASIVES:
Learning About Invasive Plant Ecology and Impacts

Houndstongue
Cynoglossum officinale

kNOweeds

LESSON 12

What's in a Name?

Grade level: K-8
Subject Areas: Biology
Duration: 30 minutes
Setting: Classroom
Season: Any
Conceptual Framework Topics: Plant ecology, habitats, invasive species

OBJECTIVES

Students will learn why some plants are considered weeds. They will understand the meanings of the terms *weed, native, non-native, invasive, and noxious*.

METHOD

Students examine plants and pictures of plants that illustrate examples of non-native ("out of place") species. These may be considered weeds, some of which are further categorized as invasive and/or noxious. They discuss how these terms are applied to different plant species.

MATERIALS

- ✎ Two small containers – Place grass in one and flowers (weeds such as oxeye daisy, toadflax, etc. if possible) in the other.
- ✎ Chalkboard or chart paper
- ✎ Photos of plants representing "out-of-place", non-native and invasive species (use samples provided or your own):
  1. a cactus in a rainforest and/or a lush plant in a desert ("doctored photos");
  2. a common Montana invasive plant, such as knapweed or leafy spurge, shown invading an area and changing the landscape;
  3. a scene of domestic flowers in a yard

BACKGROUND

There are many terms used to describe plants growing in ways and places that are undesirable to people. Some of these terms are used interchangeably by some people while others make very clear distinctions among how the words are used. This may create misunderstanding or confusion among those attempting to manage plants, let alone someone just beginning to learn about the subject!

Weed is a subjective word used to describe any plant growing where it is not wanted, for various reasons.

The term *native* (or *indigenous*) is applied to species that are growing in a region where they occur without having been transferred there through direct or indirect human actions. These species have adapted to the environmental conditions of their native range, including the influence of other species, over thousands or millions of years. (Species living in North America prior to European settlement are generally considered native.) *Non-native* species (also referred to as *alien, exotic, foreign, introduced,* or *non-indigenous*) are those growing outside of their known native, natural or historic range. A non-native species may be from another continent, another part of the same continent, or even from a different part of the same region. For example, in Montana there are non-native species that are from other continents (e.g., Russian knapweed), other parts of North America, and different parts of the Rocky Mountains (e.g., Colorado blue spruce). Some plants are introduced intentionally, as ornamentals, livestock forage, windbreaks, or to improve wildlife habitat. Others are transported unknowingly by being mixed with other plants or seeds, or adhered to vehicles, shoes, clothing, livestock, pets, or other mobile items.

Many non-native species do not grow well in their new habitat because they have not adapted to the particular conditions present there. In Montana, for example, many species may not be able to survive the low moisture levels found in Montana soils throughout much of the growing season, or they may not tolerate the extreme cold temperatures during the winter. These species may not survive at all without assistance from humans, or they may grow only near water sources or in sheltered sites.

Other introduced species, however, come from similar habitats and are well-adapted to the growing conditions found in their new range. Some of these species are also “freed” from the predators, diseases, or close competitors of their native range, and may spread rapidly and displace other vegetation. These are considered *invasive*. The National Invasive Species Information Center (NISIC) defines invasive thus:

An 'invasive species' is defined as a species that is 1) non-native (or alien) to the ecosystem under consideration and 2) whose introduction causes or is likely to cause economic or environmental harm or harm to human health. Invasive species can be plants, animals, and other organisms (e.g., microbes). Human actions are the primary means of invasive species introductions.

The application of the term invasive, like that of weed, is somewhat subjective and depends on variable human values.

Noxious weeds are invasive plants that have been given special designation through a state or federal law. These laws are designated to protect agricultural production and natural areas by mandating and regulating the control of invasive plants.

Why should we care about invasive plants?
Invasive plants can:

- Reduce agricultural production, including livestock forage
- Displace native vegetation, including rare plants
- Degrade or eliminate habitat for wildlife
- Increase soil erosion
- Alter the frequency and intensity of fires
- Alter hydrologic regimes and degrade water quality and fish habitat
- Decrease ecosystem stability by lowering biodiversity and interrupting natural processes and interactions among species

PROCEDURE

1. Begin by showing your students the two containers filled with grass and flowers. Ask them to describe what they see in each. How are the contents of the containers the same and how are they different?

2. Now ask the students if they have heard of weeds. Ask them what a weed is. If necessary, give them the definition above and discuss its subjective nature. Ask them if they think the plants in the containers are *weeds.* Explain that if you are trying to grow grass, a flower is considered a weed. If you are trying to grow flowers, grass is considered a weed. Ask them if they know of any weeds that can be found at their school, home, park, etc. How might two people have different ideas about whether a particular plant is a weed or not?

3. Now show the students the picture of the tropical plant in the desert (Photo 1). Ask them to describe what they see. What's wrong with this picture? Where do these plants usually grow? Explain the terms *native* and *non-native*, or *introduced* species.

4. Next show students the pictures of knapweed and leafy spurge (Photos 2 and 3) from http://mtwow.org.) Ask them what they notice about this picture. They may not notice anything unusual. Explain that these are also non-native species. They differ from the ones in the first picture because they are *well-adapted* to where they are growing, since they came from (evolved) in a similar place, or *habitat.* Are they considered weeds? Remind them of the definition. It depends on the perspective, although most people consider these species weeds in Montana. Would they be considered weeds in Eurasia where they are native?

5. Show the picture of cultivated flowers in a garden or a lawn (Photo 4) and discuss these questions again.

Extensions
Have students research and prepare a short report on one of the noxious weeds of Montana, using one of the resources listed in this guide or others. Students can share their reports with the class.

6. Now ask your students what differences they notice between the last two pictures. In one photo, the non-native plants are *invasive*—they are taking over, or invading, the other vegetation around them and they are identified as *invasive plant species* by land managers. In the garden photo, they are simply non-native or exotic species which, at least at this time, do not seem to pose any threat to the landscape and were actually planted in this location. Review again how the terms might apply. Are they native or non-native? Are they invasive? Are they weeds? Discuss until you feel your students understand the terms.

7. Ask students if they can think of any problems that might be caused by invasive plants. Help them come up with the items on the list above – and any others they can think of! Ask them to make a list of how invasive plants might affect their own lives.

8. Explain how the term *noxious* is used to designate certain invasive species and that there are laws that require the control of noxious species, because of the reasons above.

PHOTO 1

PHOTO 2

PHOTO 3

PHOTO 4

Photo: J. Carlson

LESSON 13

A Weed by Any Other Name…

Grade level: 6-12
Subject Areas: Biology
Duration: 1-2 class periods
Setting: Classroom
Season: Any
Conceptual Framework Topics: Plant ecology, habitats, invasive species

OBJECTIVES

Students will understand the meanings of the terms *weed, native, non-native, invasive,* and *noxious*. They will learn why invasive plants cause ecological damage and affect humans.

METHOD

Students watch a slideshow (PowerPoint) that challenges them to consider and discuss examples of non-native ("out of place") species, some of which are considered weeds, some of which are invasive and noxious. They discuss how these terms are applied to different plant species, and how context and perspective influence how and when they are used.

MATERIALS

- ✎ Introductory PowerPoint from the *kNOweeds Guide* CD or at **http://missoulaeduplace.org/weeds_curriculum.shtml**
- ✎ White or chalk board for brainstorming

BACKGROUND

There are many terms used to describe plants growing in ways and places that are undesirable to people. Some of these terms are used interchangeably by some people while others make very clear distinctions among how the words are used. This may create misunderstanding or confusion among those attempting to manage plants, let alone someone just beginning to learn about the subject!

Weed is a subjective word used to describe any plant growing where it is not wanted, for various reasons.

The term *native* (or *indigenous*) is applied to species that are growing in a region where they occur without having been transferred there through direct or indirect human actions. These species have adapted to the environmental conditions of their native range, including the influence of other species, through thousands or millions of years. (Species living in North America prior to European settlement are generally considered native.) *Non-native* species (also referred to as *alien, exotic, foreign, introduced,* or *non-indigenous*) are those growing outside of their known native, natural or historic range. A non-native species may be from another continent, another part of the same continent, or even from a different part of the same region. For example, in Montana there are non-native species that are from other continents (e.g., Russian knapweed), other parts of North America, and different parts of the Rocky Mountains (e.g., Colorado blue spruce). Some plants are introduced intentionally, as ornamentals, livestock forage, windbreaks, or to improve wildlife habitat. Others are transported unknowingly by being mixed with other plants or seeds, or adhered to vehicles, shoes, clothing, livestock, pets, or other mobile items.

Many non-native species do not grow well in their new habitat because they have not adapted to the particular conditions present there. In Montana, for example, many species may not be able to survive the low moisture levels found in Montana soils throughout much of the growing season, or they may not tolerate the extreme cold temperatures during the winter. These species may not survive at all without assistance from humans, or they may grow only near water sources or in especially sheltered sites.

Other introduced species, however, come from similar habitats and are well-adapted to the growing conditions found in their new range. Some of these species are also "freed" from the predators, diseases, or close competitors of their native range, and may spread rapidly and displace other vegetation. These are considered *invasive*. The National Invasive Species Information Center (NISIC) defines *invasive* thus:

An 'invasive species' is defined as a species that is 1) non-native (or alien) to the ecosystem under consideration and 2) whose introduction causes or is likely to cause economic or environmental harm or harm to human health. Invasive species can be plants, animals, and other organisms (e.g., microbes). Human actions are the primary means of invasive species introductions.

The application of the term invasive, like that of weed, is somewhat subjective and depends on variable human values.

Noxious weeds are invasive plants that have been given special designation through a state or federal law. These laws are designated to protect agricultural production and natural areas by mandating and regulating the control of invasive plants.

Why should we care about invasive plants? Invasive plants can:

- Reduce agricultural production, including livestock forage
- Displace native vegetation, including rare plants
- Degrade or eliminate habitat for wildlife
- Increase soil erosion
- Alter the frequency and intensity of fires
- Alter hydrologic regimes and degrade water quality and fish habitat
- Decrease ecosystem stability by lowering biodiversity and interrupting natural processes and interactions among species

PROCEDURE

1. Begin the ***Introduction to Weeds*** PowerPoint and encourage your students to consider and discuss the concepts and terms introduced. Use the following notes for each slide to encourage the discussion.

Slide No.	Notes
1.	Discuss that they are all growing in places most people would not want them to grow. They are "out of place." If the term "weed" doesn't come up, ask students if they consider them weeds. Ask for their definitions of a weed.
2.	Discuss the subjective nature of the word "weed" and how its meaning might vary from person to person, depending on perspective.
3.	Ask them to describe what they see. What's funny about this picture? Why? Where would this plant usually grow? Have they heard of native species?
4.	Discuss the terms native and indigenous.
5.	Discuss non-native species and then ask students how non-native plants might be introduced to a new place. Brainstorm a list.
6.	Did they think of all of these modes of introduction? Have they thought of others not on this list?
7.	Ask them what they notice about this large picture. Explain that these are also non-native plants. They differ from the ones in the desert picture they just saw because they are well-adapted to where they are growing, since they came from (evolved) in a similar place, or habitat. Are they considered weeds? Remind them of the definition. It depends on the perspective.
8.	Discuss the differences between non-native plants like knapweed and garden flowers. In one case, the non-native plants are invasive—they are taking over, or invading, the other vegetation around them and they are identified as invasive plant species by land managers. In the garden photo, they are simply non-native, introduced, or exotic species which, at least at this time, do not seem to pose any threat to the landscape.
9.	Ask what might make a plant invasive. Brainstorm ideas.
10.	Did they think of all of these points? Now ask what kinds of traits they think might make a plant successful at invading a new area. Make a list.
11.	Discuss.
12.	Discuss. Now ask if they have heard of the term "noxious weeds". Can they deduce what it means?
13.	This is the only one of these terms that has any legal meaning.
14.	Noxious weeds have been spreading rapidly for the past 100 years. For example, spotted knapweed arrived on the west coast in 1893 on the San Juan Islands in Washington. By 1920, this weed had established in over 24 counties in three northwestern states, with several large infestations near Missoula. Now, spotted knapweed has been reported from every county in the western United States and has invaded about five million acres in Montana alone.
15.	How many Noxious Weeds of Montana can your students name?
16.	Can your students identify any of these plants? Why might it be important? Besides being legally responsible for controlling noxious weeds, why should they care about invasive plants? Can they think of problems invasive plants might cause? Brainstorm a list.
17.	Did you think of all these? Discuss these problems caused by invasive plants.
18.	Discuss these problems caused by invasive plants. Are there more?
19.	Can your students think of personal reasons to care about invasive plants? Are there places they like to go that have been invaded by noxious weeds? What can they do personally to help prevent the spread of invasive plants?

2. Next, discuss in small groups or as a class the following scenarios:

- You work for the U.S. Department of Agriculture, and a nursery company requests approval to bring a new species of plant into the U.S. for use as an ornamental plant. What kinds of questions would you want to ask about this plant to determine if it is likely to become invasive?

- You are conducting a survey to discover the distribution of an invasive plant species that colonizes disturbed areas and has just entered your county. Draw a diagram or map of where you would expect it to occur. Now, assume it is 15 years later and no one has tried to control this species. How has its distribution changed? Draw an updated map of its distribution. Would the distribution be different if control measures had been taken?

3. Have students research one of the noxious weeds of Montana, using resources listed in this guide or others. They can create an invasive species profile using the attached worksheet or their own ideas. You might want to expand it into a small poster requirement with class presentations.

Name ____

Invasive Plant Profile

Species:

Country or area of origin:

How was it introduced to the U.S.? To Montana?

When and where was it introduced?

What is its current distribution in the U.S. and in Montana?

What characteristics make it a successful invader?

What kind(s) of habitat does it live in?

Does it invade only disturbed areas or also undisturbed sites?

Does it seem to outcompete or displace other plants where it invades?

Does anything in Montana eat it? If so, what?

What problems does it cause where it invades?

Are there successful measures to control it? If so, what are they?

Is it being controlled locally?

LESSON 14

Noxious or Native?

Grade level: 2-8
Subject Areas: Biology, language arts
Duration: 45 minutes
Setting: Indoors
Season: Any
Conceptual Framework Topics: Plant biology, noxious weeds, invasive species ecology

OBJECTIVES

Students will be able to identify at least two Montana noxious weeds and two Montana native plants, and name several characteristics common to all plants.

METHOD

Students write descriptions of plants for others to read and then identify the plant from a selection of plant photos.

MATERIALS

- ✎ Copies of photos of two noxious weeds and two native plants (1 full set per small group of students)
- ✎ Pencils
- ✎ Blank cards (one per student)
- ✎ Journals or other paper

BACKGROUND

Which plants are considered to be weeds and which are considered to be desirable in a landscape depends on your view. For example, one person may encourage edible plants like dandelions on their property, while another may work hard to eliminate them. Regardless of their desirability in a landscape, all plants have certain characteristics in common. However, it is their distinguishing characteristics that allow us to identify different species and determine if it will be necessary to remove the plant or if it "belongs" in a certain location. Learning to identify plants is the first step in managing vegetation. To correctly identify a plant you must identify a number of its unique characteristics. A plant identification key, plant guide, or other resources may be necessary to determine the identity of a particular species. Once identified it is possible to locate information about the plant to find out if it is considered invasive and how it may impact the local environment if left unchecked, as well as recommendations for its control.

Identification starts with gathering information about a plant. Some typical questions you might want to ask to gather this information could include the following:

Microhabitat: Does the organism always occur in the same "zone"? Then, consider the conditions it is growing under, such as temperature, moisture level, sunlight/shade, soil type.

Distribution: Does it occur in clumps, or is it on its own, far from others of the same species? If in clumps, do they seem randomly distributed, or do you see

Common Tansy
Tanacetum vulgare

a pattern? Is it always associated with the same plant species, or do you find it with a variety of other plants?

Growth Form: How does the plant hold itself up when it doesn't have a skeleton? Is it woody or herbaceous (non-woody)? If it's woody, is there one main trunk (trees), or are there several (shrubs)? Does the plant stand up by itself, sprawl along the ground, or use something else for support (vines)?

Leaf Type: Does the leaf look like: a regular broad-leaf, with a little stem (petiole) and a flat, wide blade? a long strap? a needle or a tiny scale? If the leaf has a petiole and blade, what shape is the blade?

Leaf Arrangement: How are the leaves arranged on a stem? Are there two leaves attached to the stem at the same point (opposite)? Are there more than two leaves attached to the same part of the stem (whorled)? Do the leaves attach to the stem in a zigzag or spiral pattern (alternate)?

Reproduction: How does the plant produce offspring? Do you see flowers on the plant? Where are the male and female parts of the flower? How do you suppose the male parts meet the female parts? Do you see fruits or cones on the plant? If so, can you find the seeds? How do you think seeds get around to new locations?

Plant Defense: How do plants protect themselves from predators? Does the plant have any spines? Do the leaves look very hairy? Are certain parts of the plant very tough and hard to digest? Does the plant have a distinct smell? Do you see evidence of anything eating the plant, or signs that something has been eating it?

Once you have enough information about the plant you will be able to identify it.

In this activity, students gain practice describing characteristics of a plant from photos, which will then be used by other students as they try to match the descriptions with the correct plant photos.

PROCEDURE

Assign students into small groups that will share a complete set of plant pictures. Ask students to view selected pictures of noxious weeds and native plants. Examples of noxious weeds of Montana that are found in every county in the state of Montana include spotted knapweed (*Centaurea stoebe*) and Canada thistle (*Cirsium arvense*). Examples of common Montana native plants are arrowleaf balsamroot (*Balsamorhiza sagittata*) and our Montana state grass, bluebunch wheatgrass (*Pseudoroegnaria spicata*). However, you may want to provide pictures of other species of local interest or concern. For pictures, you can go to any of the following web sites:

- Smithsonian's United States National Herbarium, which contains a bank of 17,000 plant images, searchable by scientific and common name at: **http://persoon.si.edu/PlantImages/frmSearch.cfm**
- The USDA Plant Database also has 40,000 searchable images of plants at: **http://plants.usda.gov/**
- Montana Plant Life at: **http://montana.plant-life.org**

Color pictures are not necessary. Black-and-white images, in fact, are useful if you do not want the students to rely on the most obvious descriptions, such as yellow for the flower of the arrowleaf balsamroot.

1. From the photos of plants distributed, each student will choose one plant to describe. Each will brainstorm and make a list of whatever descriptions come to mind in their journal or on a piece of paper, and then edit those thoughts by writing a complete sentence or two describing the plant on a blank card. The goal is to give such telling details that a classmate will be able to identify the plant by the description. Students should ask themselves: *How can I say the most about this plant in two sentences or less?* The only stipulations are that they cannot give the name of the plant, if they know it, or describe any characteristic not found in the photograph (e.g., the place it is found in great numbers locally). Encourage them to use simile and other figurative language in their descriptions. Let them know that the common names for many plants can be descriptive. For example, the buttercup flower is cup-shaped and is butter yellow.

2. Allow a set time for the exercise—five to ten minutes. Ask students to write their names or initials in a corner of the card when they are done. Collect the cards and redistribute them at random, so that each student has another's card. Everyone will now try to deduce which plant the assigned card describes. Ask students to circle the words or phrases on the card that seem especially descriptive.

3. Go around the room and ask each student to read the description on the lined side of the assigned card and to announce his or her guess of the plant in question. In a discussion, have students confirm or correct the guesses of their classmates. Ask those who guessed correctly: *What were the words that best described the plant?* If a guess was incorrect: *What other words might have been helpful?*

4. Conduct a class brainstorming session in which students suggest words and phrases that describe all of the plants. Record the responses on the board. Use the brainstorming list to compose, as a class, a paragraph that answers the question *What is a plant?*

Extensions

Apply the lesson to native and non-native plants in the schoolyard, having students find the plants, then take photos or samples of the plants to repeat this activity.

LESSON 15

The Key to Montana Weed I.D.

Grade level: 4-8
Subject Areas: Biology
Duration: 30 minutes
Setting: Classroom
Season: Any
Conceptual Framework Topics: Species, classification, identification, tools and technology, invasive plants in Montana

OBJECTIVES

Student will understand what a dichotomous key is and how to use one. They will learn to identify distinguishing characteristics that separate one plant species from another. They will be able to identify up to 6 of Montana's noxious weeds using a simple key.

METHOD

Students use a very simple key to "identify" different types of candy. They then use a more sophisticated but easy-to-use key to identify noxious weeds of Montana.

MATERIALS

Examples of the following weed species. You can use the photos at the end of this lesson, plastic specimens, plants you have pulled or dug up, or dried specimens:

- Canada thistle *(Cirsium arvense)*
- spotted knapweed *(Centaurea stoebe)*
- Dalmatian toadflax *(Linaria dalmatica)*
- houndstongue *(Cynoglossum officinale)*
- leafy spurge *(Euphorbia esula)*
- field bindweed *(Convolvulus arvensis)*
- The **Dichotomous Key to Noxious Weeds of Montana worksheet**
- The **"Candy Key" worksheet** (used with permission from the *Alien Invasion* Weed Curriculum)
- Five different kinds of candies: chocolate "kisses," Jolly Ranchers, lollipops, Smarties or SweeTARTS, and Starbursts, mixed together in a bowl.

BACKGROUND

Botanists, naturalists, resource managers, and others interested in recognizing plants and animals often use **dichotomous keys** to correctly identify species. *Dichotomous* means "divided into two parts." In a dichotomous key, the user is given a series of choices between two statements about characteristics of the organism. Each choice leads to another pair of statements until the name of the organism is reached.

Using a key to identify plants helps students practice observation skills and learn how to use similarities and differences to distinguish between species. Close observation allows students to see the variation in plant characteristics, and actively engaging them in identification of weeds will facilitate retention of knowledge about the invasive species in their area.

Teacher's Key to Dichotomous Key

F	spotted knapweed
B	Canada thistle
E	Dalmatian toadflax
C	houndstongue
A	leafy spurge
D	field bindweed

PROCEDURE

Ahead of time: Read through the lesson and collect the necessary materials. Label any plant specimens or models you collect with capital letters so that your students can use those to identify each specimen by name (see **Weed Key** worksheet). Practice using the keys so that you are familiar with them.

1. Begin the lesson by asking students what kinds of clues they use to distinguish one classmate from another. They may mention hair color, size, eye color, gender, etc. Now explain that differences between things can help people identify not just individuals but also what kind or ***species*** a plant or animal is. A dichotomous key is a tool that can be used to help people identify species of things. Explain that the students are going to use a dichotomous key to identify weeds that grow in their neighborhood. First, however, they are going to practice using a key that will help them identify different types of candy.

(For younger students, you may want to now demonstrate how to use the candy key with a piece of candy in front of the class.)

2. Pass out a copy of the candy key to each individual or group of students (small groups can work nicely because each student will be able to help identify several pieces of candy.) Then pass the bowl of candy around and have each student take two different pieces. Tell them they will be able to keep or eat the candy IF they are able to correctly identify it using the key. Have them determine the "scientific" name of their candy, checking their work for accuracy.

3. Tell them that now that they know how to use a dichotomous key, you will give them one to help them identify real weeds that have invaded Montana and live near them. Pass out a **Weed Key** to each student. Explain that this key looks different but works the same way. **Make sure they understand that they should start at number 1 with each weed they are trying to identify.** Again, you may want to demonstrate with one specimen. Now hand out the weed specimens or photos. If there aren't enough specimens for each group to have one of each kind, they can pass them around.

4. Have the students go through the key for each weed, until they have found the name for each. You may want to monitor their progress during the first one to make sure they understand and are using the key correctly.

5. When students think they have correctly identified the weeds, ask them to share their results. If there are disagreements or incorrect answers, ask them to go through and explain how they reached the name they decided on. Discuss whether the key was detailed and accurate enough to reach the correct conclusions. See if they have any suggestions for improvements, or if they might construct one differently. (Answer key to the dichotomous key is in the column at left).

6. Ask if they have seen some of these weeds before, and if so, where. Do they think they might be able to better identify weeds now that they've learned about them using the key?

7. Show your students the Dichotomous Key to Plants as an example of a "real" key used to identify plants and discuss what it would be like to use such a key. Ask why they think some of the language is so "technical."

Extensions

Have them research the problems associated with these weed species and why they are designated noxious weeds in Montana, using one of the resources listed below or in the **Resources** section of this guide.

Take students on a field trip (even a walking one from the school if there are appropriate ones nearby) to a "weedy" site and see if they can identify any weeds from the key.

Have your students make up their own key for native or invasive species from their schoolyard, yard, or nearby area.

Suggested Resources for learning more about noxious weeds in Montana:

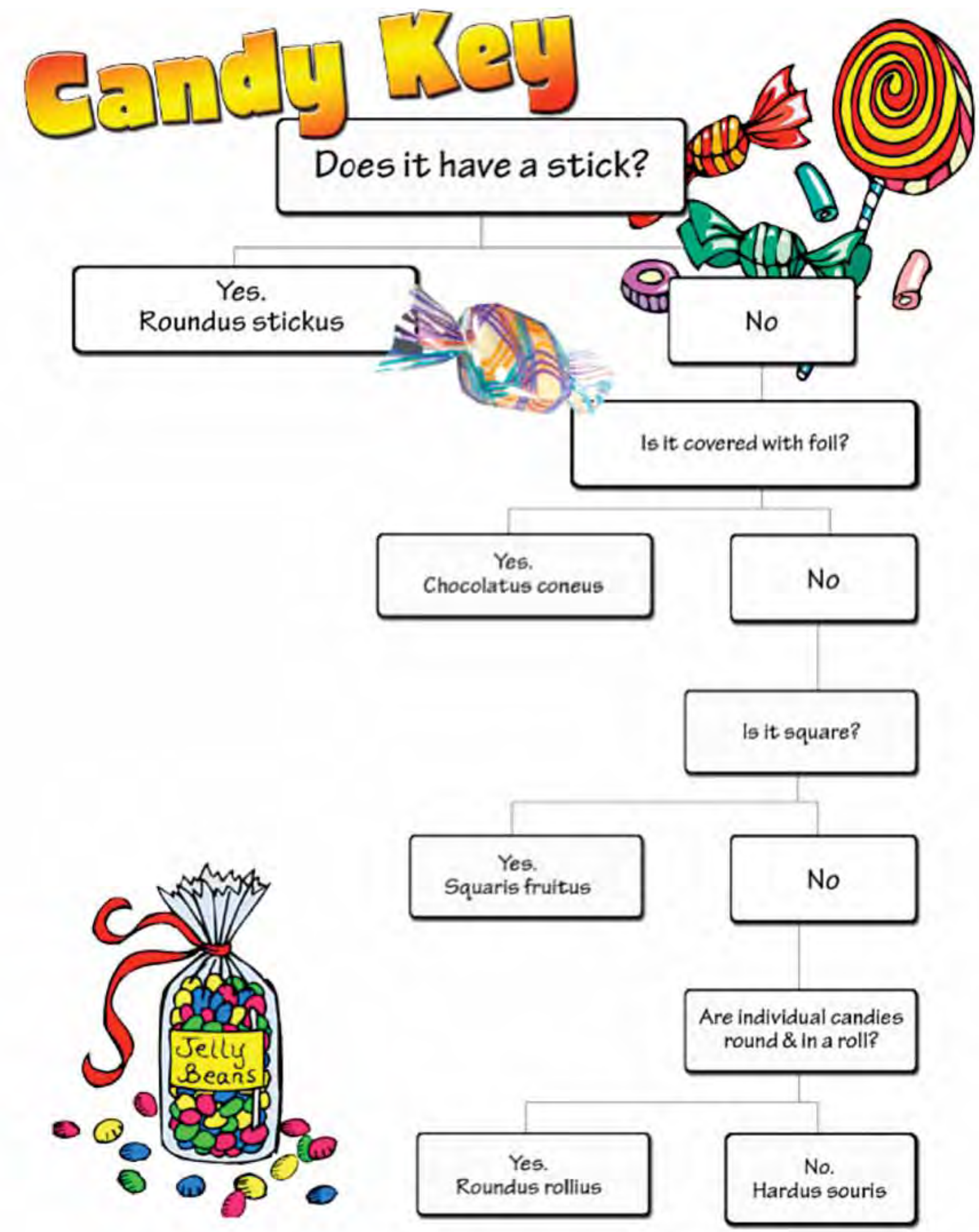
http://weedcenter.org
The Center for Invasive Plant Management

www.weedawareness.org Montana's Statewide Noxious Weed Awareness and Education Campaign Website

http://plants.usda.gov/index.html
The INVADERS Database System at The University of Montana

http://acwm.co.la.ca.us/PDF/invasive_weeds_book.pdf
Invasive weeds booklet for elementary students online

http://mtwow.org/
Montana War on Weeds


Candy Key
Does it have a stick?
Yes. Roundus stickus
No
Is it covered with foil?
Yes. Chocolatus coneus
No
Is it square?
Yes. Squaris fruitus
No
Are individual candies round & in a roll?
Yes. Roundus rollius
No. Hardus souris
Jelly Beans

Name ______________________________

Dichotomous Key to Noxious Weeds of Montana

• START HERE FOR EACH PLANT:

1 I grow upright on a single main stem, or several branching stems. I may start with a rosette, or a cluster of leaves growing close to the ground.

If this sounds like me, go to #2.

OR

I grow on a creeping vine close to the ground, twisting around other plants, or up fences. I have smooth, arrow-shaped leaves 1-2 inches long and bell-shaped, white or pink flowers.

I am: field bindweed *(Convolvulus arvensis)*

2 My flowers are purple or reddish-purple.

If this sounds like me, go to #3.

OR

My flowers are yellow or greenish-yellow.

If this sounds like me, go to #4.

3 My leaves are large and wide, undivided into segments, with smooth edges and broad tips. My leaves are covered with fine, soft hairs and have a net-like pattern of veins. My reddish-purple flowers grow along a vertical stalk.

I am: houndstongue *(Cynoglossum officinale)*

OR

My leaves are oblong and narrow, being divided or lobed into many sections, with pointed or round, narrow tips. My light purple or pink flowers grow singly or in small groups at the end of stems.

If this sounds like me, go to #5.

4 My leaves are pale green, waxy, and heart-shaped, and clasp around the stem at their base. My bright yellow flowers grow upright on a long raceme, or stalk at the top of me.

I am: Dalmatian toadflax *(Linaria dalmatica)*

OR

My leaves are pale green, long, and narrow with smooth edges. My green flowers have yellow or greenish bracts (petal-like leaves) below them. They grow in a flat-topped or rounded cluster at the top of me.

I am: leafy spurge *(Euphorbia esula)*

5 My long, thin leaves have narrow lobes, or segments, with rounded tips.

I am: spotted knapweed *(Centaurea stoebe)*

OR

My leaves have sharp spines on the end of each lobe and at the tips.

I am: Canada thistle *(Cirsium arvense)*

Write the letter on each plant sample or photo beside the correct name:

________ spotted knapweed

________ Canada thistle

________ Dalmatian toadflax

________ houndstongue

________ leafy spurge

________ field bindweed

kNOweeds ACTIVITY

A

B

Photo: Leslie J. Mehrhoff, University of Connecticut, Bugwood.org

C

Dichotomous Key to Noxious Weeds of Montana

D

E

F

Dichotomous Key to Noxious Weeds of Montana

Plants of the Sierra Nevada

Key to Dicotyledon Families

Sample key from:
www.backcountryrangers.com

A Plants parasitic or saprophytic, often not green
B Petals absent; plants usually green
C Parasite on upper limbs of trees - LORANTHACEAE (Not Edible)
CC Root parasite; leaves alternate, entire, oblanceolate - SANTALACEAE (Not Edible)
BB Petals present, more or less united
C Stamens more than 5 - PYROLACEAE
CC Stamens 5 or less
D Twining or trailing vines, not on roots - CUSTUTACEAE (Not Edible)
DD Root parasites - OROBANCHACEAE
AA Plants not parasitic or saprophytic or not completely so, always greenish
B Plants woody throughout (not just base)
C Leaves opposite
D Leaves compound
E Leaves palmately compound - HIPPOCASTANACEAE
EE Leaves pinnately compound or trifoliolate
F Vines - RANNUNCULACEAE (Clematis) (Not Edible)
FF Shrub or tree
G Fruit a samara
H Leaflets usually 3 - ACERACEAE
HH Leaflets 3 to 7 - OLEACEAE
GG Fruit a capsule or drupe
H Leaflets 3; fruit a dry capsule - STAPHYLEACEAE (Not Edible)
HH Leaflets 4 to 7; fruit a fleshy drupe - CAPRIFOLIACEAE *(Sambucus)*
DD Leaves simple
E Petals more or less united
F Leaves narrow-elliptic, margins revolute; boggy places - ERICACEAE *(Kalmia)*
FF Leaves broader; margins not strongly revolute
G Flowers irregular, leaves usually sessile; fruit a capsule - SCROPHULARIACEAE
GG Flowers usually regular; leaves petioled; fruit usually fleshy - CAPRIFOLIACEAE
EE Petals separate or none
F Stipules with thick corky persistent bases - RHAMNACEAE *(Ceanothus)*
FF Leaves without stipules
G Leaves serrate (except sometimes *Philadelphus* in SAXIFRAGACEAE)
H Leaves palmately lobed - ACERACEAE
HH Leaves oblong to roundish, without lobes
I Flowers 4-merous; petals 1 mm long - CELASTRACEAE (Not Edible)
II Flowers usually 5-7-merous; petals more then 6 mm long - SAXIFRAGACEAE
GG Leaves entire
H Leaves aromatic - CALYCANTHACEAE (Not Edible)
HH Leaves not aromatic
I Leaves thick, often scurfy; plants dioecious - GARRYACEAE
II Leaves thin; flowers perfect - CORNACEAE
CC Leaves alternate, whorled, bunched or basal
D Flowers in catkins
E Fruit an acron or bur - FAGACEAE
EE Fruit a winged nutlet, smooth nut, or capsule

LESSON 16

We Can't Eat Weeds!

Grade level: 5-12
Subject Areas: Biology, social studies, math, economics
Duration: 2 class sessions
Setting: Classroom
Season: Any
Conceptual Framework Topics: Agriculture, economics of plants, impacts of invasive plants, invasive plant management

OBJECTIVES

Students will understand the importance of agriculture in Montana and how weeds impact the agricultural industry and the food we all eat.

METHOD

Students search for food produced in Montana and learn how many different types of agricultural products are grown in the state. They calculate production and economic values of different crops using agricultural statistics data, and use economic thresholds to determine whether to use weed controls at different levels of weed infestations.

MATERIALS

✎ **We Can't Eat Weeds Worksheets: Montana Farm** and **Ranch Products Hunt, Crop Production in Montana, and Economic Threshold Estimate**
✎ We Can't Eat Weeds Excel Worksheet file from *kNOweeds* CD (optional)

BACKGROUND

Approximately 60 million acres of Montana's 93 million acres are used for farm and ranch production. Most of this land is rangeland used for cattle and sheep, with about 17.5 million acres used for growing crops. The average size of a farm in Montana is 2,120 acres. Additionally, some government land is leased for agricultural purposes. About five percent of Montanans are farmers and ranchers, and a total of 17 percent of the population hold agriculture-related jobs.

Agriculture contributes more than $ 2.4 billion to the state's economy annually. Of that $ 2.4 billion, livestock contributes about half. The primary type of livestock in Montana is cattle. There are 2.6 million beef cattle in Montana and about 18,000 dairy cows. Sheep are the second most numerous, and Montana's sheep produce over 4 million pounds of wool annually. Additional livestock include horses, swine, poultry, and llamas. Montana is generally in the top 5 to 10 producers of honey in the United States each year, producing about 9 million pounds annually. Montana's primary crop is wheat. Other crops grown in Montana include barley, oats, berries, cherries, corn, hay, mint, sugar beets, sunflowers, apples, canola, potatoes, dry beans, field peas, flax, grapes, garlic, lentils, safflowers, mustard, squash, alfalfa, and many more.

Montana farmers and ranchers spend $100 million each year trying to control invasive plants. For example, farmers and ranchers applied 4,737,000 pounds of chemical herbicides to wheat crops alone in Montana in 2008. Unfortunately, this expensive effort isn't entirely successful, due to the tenacious characteristics of invasive plants. Controlling weeds on agricultural lands is complex. Some agricultural practices, such as tilling, grazing and burning may have either positive or negative effects on weed growth, depending on many factors (see ***Lesson 42: Burning Questions*** for more on this topic). For example, grazing can reduce native plant coverage, disturb the ground, and introduce weed seeds through hay or manure, all factors that tend to encourage invasive plant growth. However, carefully timed grazing can be an important tool in controlling some weed species.

The effects of invasive plants on crop and forage production are complex and variable. They depend on many variables, including the species and densities of both the desired plants and the weeds (for example, allelopathic species or tall, shading plants will have greater effects); the agricultural methods employed (e.g., different tilling or grazing intensities); the timing of planting or growth of desired species; and factors like weather and growing conditions.

Integrated Pest Management (IPM) is a system for reducing crop losses from insects, weeds and plant diseases. IPM uses all available control practices such as crop rotation (changing what's grown in a field), mechanical cultivation, changing planting and harvesting times, biological control (using other living organisms to control pests), and chemical control. Using several methods of control is usually more effective than relying on a single management practice. One goal of IPM is to reduce pest damage to an acceptable level and minimize the risks of pesticides to human health and the environment.

Scouting fields for weeds and basing treatment decisions on economic thresholds is an important part of IPM. The principle of using economic thresholds is that weeds are not controlled until they reach a level that is economically damaging. The predicted loss from weeds must be more than the cost of control. If the number of weeds are not high enough to cause an economic yield loss, control is not recommended. In some cases, this means that weeds are allowed to remain in the field. However, this course of action often depends on several factors, including the aggressiveness of the plant species, and if it is just initiating invasion and might be quickly controlled, or is already established.

Economic thresholds are based on how much damage a pest may cause if not controlled, the predicted crop yield, the estimated selling price, the cost of control, and other factors.

PROCEDURE

1. Ask your students if they know what Montana's biggest business is in economic terms. Explain that it is agriculture, or farming and ranching. See if they can guess how much of the state land area is farms and ranches, and how much money it contributes to the state's economy each year. How many different agricultural products (crops and livestock) can they list that are grown in Montana? Make a list on the board and see how well their list matches the one on the **Montana Farm and Ranch Products Hunt** sheet. Are they surprised by any that are grown here? Are they surprised by any that aren't?

Give your students the **Montana Farm and Ranch Products Hunt** worksheet and go over the directions with them. Ask them if they think it will be difficult to find the items on the list. Give them however much time you think they will need to complete it. If they are only going to look for items at home, they can complete it in one night. If they are going to go to the store you may need to give them a few days.

2. When they have returned with their sheets, discuss what they found. Were they able to find many items that were actually grown in Montana? Can they think of any advantages of being able to buy products grown in Montana? (Shipping expenses, energy use, supporting state's economy, etc.)

3. Give your students the **Crop Production in Montana** sheet and make sure they understand all the information. Go over an example to show them how to calculate the production and value amounts. Have them complete the work and answer the questions. (Option: import the data from the table into a spreadsheet and have them do the calculations that way). When they have finished, discuss the following:

Does this mean that crops with the highest yields and/or values brought in the most income? Why or why not? *(Costs are not considered in this calculation)*

What are some factors that might impact how much a farmer makes from crops? What are the costs associated with crop production?

What kinds of things might affect how much a farmer produces?

Ask your students what kinds of challenges there are to growing crops and livestock in Montana. They may mention weather, pests, weeds, predators, and drought. Discuss how weeds might impact agriculture. They should understand that invasive plants compete with crops for water, soil nutrients, sunlight and space. Can they affect livestock? Many invasive plants are unpalatable to livestock or even toxic, and they can reduce the amount of good forage plants, such as native bunchgrasses, available for livestock to eat.

Extensions

Have your students research the agricultural production in their county. How does it compare to Montana as a whole? Which products are most abundant? Which noxious weeds are found in their county?

Have them research the effects of weeds on Montana crop or forage species and the current, true costs of some weed control methods and make decisions about areas based on infestation rates.

4. Now your students can use economic thresholds to decide if weed control, such as an herbicide application, is necessary for particular crop and weed situations. Explain to them that growers must consider economic factors when deciding if and when to control an invasive plant species. They must determine whether the cost of controlling weeds is less than the cost of letting them grow. Ask how they would determine that. What information would they need to have? When they have figured out as much as they can, give them the **Economic Threshold Estimate** sheet and have them work out the problems. Follow up with a discussion:

What are the advantages to using an Economic Threshold model? *(Save money, controls such as chemicals are used only when necessary, reducing environmental impacts, etc.)*

What are some potential problems with using this method? *(Some pests may be allowed to become too abundant and eventually more difficult or costly to control; may not take long-term effects into consideration, etc.)*

What are some other factors a producer might want to consider?

Name ____________________

Montana Farm and Ranch Products Hunt

Directions: Look in your kitchen or at the supermarket to find the foods made from, or that have an ingredient made from the kinds of crops and livestock that are raised in Montana. See how many of these crops you can find. Try to find three foods or ingredients for each – write down the ingredients or products that are made from each group. Note if you find evidence that the ingredients were actually grown in Montana.

Crop				**Produced in Montana?**
wheat	______	______	______	______
barley	______	______	______	______
oats	______	______	______	______
berries	______	______	______	______
cherries	______	______	______	______
corn	______	______	______	______
mint	______	______	______	______
sugar beets	______	______	______	______
sunflowers	______	______	______	______
apples	______	______	______	______
canola	______	______	______	______
potatoes	______	______	______	______
dry beans	______	______	______	______
field peas	______	______	______	______
flax	______	______	______	______
grapes	______	______	______	______
garlic	______	______	______	______
lentils	______	______	______	______
safflowers	______	______	______	______
mustard	______	______	______	______
squash	______	______	______	______
beef	______	______	______	______
chicken	______	______	______	______
pork	______	______	______	______

Name ____

Crop Production in Montana

This table shows some of the most abundant crops grown in Montana. Fill in the blank columns to answer the questions at the bottom of the page.

Commodity	Acres Planted	Acres Harvested	Amount per acre	Total Production in State	Price per unit	Total Value in Dollars
Wheat	5,170,000	5,065,000	29.6 bushels		$7.60 / bushel	
Barley	900,000	720,000	44 bushels		$4.25 / bushel	
Dry Beans	18,300	16,600	1,670 pounds		$24.20 / 100 lbs	
Chickpeas (Garbanzo)	8,500	8,200	1,190 pounds		$16.20 / 100 lbs	
Safflower	38,000	36,500	830 pounds		$16.50 / 100 lbs	
Flaxseed	21,000	20,000	9 bushels		$13.10 / bushel	
Corn for Grain	84,000	38,000	140 bushels		$4.75 / bushel	
Hay		2,600,000	1.96 tons		$76.00 / ton	
Oats	75,000	35,000	50 bushels		$2.55 / bushel	
Potatoes	11,300	11,200	33,000 pounds		$9.85 / 100 lbs	
Lentils	87,000	85,000	1,150 pounds		$17.10 / 100 lbs	
Peas	235,000	217,000	1,700 pounds		$9.50 / 100 lbs	

Which crop was the most abundant in the state in bushels? ________________

Which crop produced the most in weight? __________________

Which crop had the highest total monetary value in the state? ________________

Which had the highest value per acre? _________________________

Name ____

Economic Threshold Estimate

Table 1 shows three different weeds and the effects they can have on crop yield if they are not controlled.

(Adapted from the University of Illinois Extension's *Natural Resources, The Environment and Ecosystems*)

Steps to Follow in Activity

1. Count the average number of weeds per 100 feet of a crop row.
2. Refer to Table 1 to find the estimated yield loss for that number of weeds.
3. Estimate the potential crop yield for the field.
4. Multiply the estimated yield loss by the predicted crop yield. This equals yield loss if weeds are not controlled.
5. Multiply yield loss by expected cash price per bushel.
6. Determine cost of weed control.
7. Subtract the cost of weed control from the cost of yield loss to determine if weed control, such as herbicide treatment, is economical.

Example

You scout a wheat field and find an average of 8 Giant Wheatkillers per 100 feet of row. Should you apply an herbicide to control these weeds?

TABLE 1

Kind of weed	Number of weeds in 100 feet of row					
Giant Wheatkiller	1	2	4	6	8	10
Kernel Smother	2	4	6	10	15	20
Boogeyweed	2	5	8	11	14	17
% of yield reduction	1%	2%	3%	6%	8%	10%

(For example: 4 wheatkiller plants in 100 feet of row will reduce wheat yield by 3%)

- Expected Yield: 30 bushels/acre
- Expected cash price per bushel: $7.60
- Cost of weed control (herbicide application, biocontrol, mechanical removal): $15.00 / acre

Step 1: 8 giant wheatkillers

Step 2: 8% yield loss (from Table 1)

Step 3: 30 bushels/acre

Step 4: (0.08) X 30 bushels = 2.4 bushels

(over)

Step 5: 2.4 bushels X $7.60/bushels = $18.24

Step 6: $15.00/acre

Step 7: Net gain or loss: $18.24 - $15.00 = $3.24/acre loss

Decision: Apply weed control according to economic threshold model

You scout a wheat field and find an average of 10 wheatkiller plants per 100 feet of row.

- Expected Yield: 28 bushels/acre
- Expected cash price per bushel: $5.00
- Cost of weed control: $15.00

1. Should you take action to control these weeds?

2. If the price for wheat goes up to $8.00/bushel, should you control the weeds?

3. If the cost of weed control drops to $10.00/acre, should you control the weeds?

TEACHER'S COMMODITIES TABLE KEY

Commodity	Acres Planted	Acres Harvested	Amount per acre	Total Production	Price per unit	Total Value in Dollars
Wheat	5,170,000	5,065,000	29.6 bushels	149,820,000 bushels	$7.60 / bushel	1,138,176,000
Barley	900,000	720,000	44 bushels	31,680,000 bushels	$4.25 / bushel	134,640,000
Dry Beans	18,300	16,600	1,670 pounds	27,800,000 lbs	$24.20 / 100 lbs	6,728,000
Chickpeas (Garbanzo)	8,500	8,200	1,190 pounds	9,639,000 lbs	$16.20 / 100 lbs	1,634,000
Safflower	38,000	36,500	830 lbs	30,295 lbs	$16.50 / 100 lbs	4,999,000
Flaxseed	21,000	20,000	9 bushels	180,000 bushels	$13.10 / bushel	2,358,000
Corn for Grain	84,000	38,000	140 bushels	5,320,000 bushels	$4.75 / bushel	26,173,000
Hay		2,600,000	1.96 tons	5,090,000 tons	$76.00 / ton	393,173,000
Oats	75,000	35,000	50 bushels	1,750,000 bushels	$2.55 / bushel	4,641,000
Potatoes	11,300	11,200	33,000 lbs	369,600,000 lbs	$9.85 / 100 lbs	36,406,000
Lentils	87,000	85,000	1,150 lbs	97,800,000 lbs	$17.10 / 100 lbs	14,398,000
Peas	235,000	217,000	1,700 lbs	368,900,000 lbs	$9.50 / 100 lbs	35,046,000

Which crop was the most abundant in the state in bushels? **Wheat**

Which crop produced the most in weight? **Hay**

Which crop had the highest total value in the state? **Wheat**

Which had the highest value per acre? **Potatoes**

LESSON 17

Plant Adaptations

Grade level: K-8
Subject Areas: Life science
Duration: 1 class session (includes a brief walking trip which perhaps can be done right around your school neighborhood) OR one 15-minute session on one day followed by a 30-minute session the next day
Setting: Classroom and a field site
Season: Spring, Summer, Fall
Conceptual Framework Topic: Plant adaptations to environment

OBJECTIVES

Students will understand that some plants have very specific adaptations that allow them to exploit different environments and survive under a range of conditions. How plants conserve water is one important adaptation that is readily observable.

METHOD

Students observe different kinds of plants and their leaves and discuss how they are adapted to differing levels of water availability. They compare plant types in varying micro-habitats around the schoolyard or other field site. They then predict traits of successful invasive species and compare their predictions to invasive species in Montana.

MATERIALS

- ✎ A variety of leaves (wide, narrow, hairy), conifer needles, a cactus plant if available.
- ✎ Hand lenses (enough for each student or to share)
- ✎ **Adaptations Worksheet**
- ✎ Photos of plants from very different environments (e.g., rain forest, desert, alpine)
- ✎ *Optional:* A stalk of fresh celery or a white carnation, jar of water and a few drops of food coloring

BACKGROUND

Plants have evolved into millions of species that have been able to survive in virtually the entire range of habitats on earth, from under the sea to the tops of high mountain peaks, from rainforests to the driest deserts on earth, from sweltering heat to freezing cold. Unlike animals, plants cannot move around to get what they need, including protection from weather and predators, and food and water. But they have developed an incredible range and variety of features that help them deal with this challenge.

One basic need of plants that varies hugely in the amount needed by type of plant and its availability from place to place is water. Some species can spend their entire lives submerged in it. Others can live on amazingly little. (In fact, there are species of geophytic (ground-loving) cacti that live in the driest places on earth, including the Atacama desert in South America, parts of which haven't had rain for hundreds of years, and receive only moisture from ocean fogs. The cacti live entirely underground, which helps them retain moisture, receiving light through the translucent desert sand.)

In Montana we have no such extreme. But we do have a wide range of moisture conditions, from the temperate rainforest of cedar and hemlock in the Northwest where more than 60 inches of precipitation fall each year, to the plains of eastern Montana where annual precipitation is usually less than 15 inches. Overall, Montana, like most of the West, is relatively arid compared to the rest of the country.

Many plants have evolved strategies for minimizing water loss. Since almost all water loss occurs when water evaporates from the leaves (through tiny openings called *stomata*), many adaptations are to the leaves. These include reduced surface area on narrow and/or small leaves (think of grasses and needles), tiny "hairs" on leaves which reflect the sun and keep leaves cooler, and thicker, tougher leaf walls and waxy leaves which help keep water in. The most extreme examples are the cacti, most of which have reduced their leaves to spines so they lose very little water, and do all their photosynthesizing through their green stems.

PROCEDURE

1. **Ahead of Time:** Look for an outdoor site where you can see patterns of plant distributions due to moisture conditions (e.g., a slope and flat area, different slope aspects (directions), a depression, drainage, or source of surface water, etc.). You may observe primarily narrow-leaved species such as grasses and small forbs growing on dry sites like south-facing slopes or well-drained flat areas, coniferous trees on north slopes, and larger-leaved plants like deciduous shrubs and trees in low areas or near surface water. In some areas these patterns may be very obvious, while in others there may be very subtle variation on a smaller scale. One thing to keep in mind is that humans may create artificial environments through ditches or other water sources.

2. In the classroom, ask your students what everything needs to survive. They may mention several things such as food, water, shelter, etc. Tell them you're focusing on water today.

3. Ask why plants need water. What do they use it for? How does water move in plants? You may want to review with them the photosynthetic process, and show them with a simple drawing how water is taken in through the roots, moves up the stems and into leaves, and then evaporates through *stomata*, tiny openings in the leaves.

4. *Optional* (if you do this step, you may want to resume the lesson the following day with step 4.) Cut the bottom inch off the stalk of celery and place the stalk into a jar of water that has several drops of food coloring in it. Ask your students what they think will happen. Leave this overnight next to a window. (The food coloring should move up the celery stalk gradually.)

5. Ask your students if they think plants ever end up without enough water to survive. What, if anything, can they do about it? Can they move to a better place? If necessary, explain that plants can't move but they have adapted over time (generations) so that some species can live in dry areas.

6. Ask them what they would do if they were hot and dry in the sun. (They may come up with wearing a sun hat, using an umbrella, getting in the shade, turning away from the sun, drink water, etc.)

7. Now show them the variety of leaves you have brought. Discuss what they see. Why might they be so different from one another? Which type grows in what kind of environment? Remind them of how water moves through plants. If necessary, help them understand how each type of adaptation (size, hairiness [called *pubescence* in plants], thickness, etc.) helps plants reduce water loss. Ask them if they can think of any drawbacks to having smaller leaves or hairy leaves. (Because plants need to gather sunlight through green leaves and stems, there is a trade-off to reducing water loss in these ways.)

8. Take a walk and look at what types of plants grow where. For example, you may notice trees growing on north slopes but not south or west slopes. Trees and bushes may grow only in draws on some mountains or hills. Deciduous trees and shrubs may be by streams and lakes or other sources of water. In the driest places you may see mostly grasses and other narrow-leaved plants. Ask students if they can explain some of the patterns they see based on what they know about plants conserving water.

9. While near one of the driest areas you find on your walk, discuss other adaptations plants might have for water loss and other factors. If you planted 2 plants in this location, one more adapted for conserving water than the other, which would probably do better?

10. Imagine that seeds from a plant that grows far away, perhaps on the other side of the world, are brought to Montana by humans in some way. What kinds of plants would probably grow best in our climate? Knowing what they now know about adaptations to conserve water and the kinds of plants that grow in their area, can they predict some of the traits that might allow plants from other areas to thrive here? Have students make a list of some of these traits, using the worksheet provided. Use this list to compare to the traits of some of Montana's noxious weed species. Students may want to look at photos or descriptions of invasive species on a web site such as **www.mtwow.org** or **montana.plant-life.org**, or in a printed resource like the *Montana's Noxious Weeds* booklet published by MSU Extension.

Extensions

Examine photos of plants from very different parts of the world (rain forests, deserts, swamps, etc.) and observe different adaptations to conditions.

Name ____

Plant Adaptations Worksheet

Traits that make it easier for plants to thrive in Montana:

Invasive plant species in Montana that have these traits:

LESSON 18

Weed Success: A Bag of Tricks

Grade level: 5-8
Subject Areas: Biology, writing, role-play
Duration: 2 class sessions
Setting: Classroom
Season: Any
Conceptual Framework Topics: Plant ecology, invasive plant management

OBJECTIVES

Students will be able to identify life-history strategies that make some plants successful invaders.

METHOD

Students brainstorm what characteristics of plants might make them successful invaders. They research noxious weed species of Montana and demonstrate traits their species uses to help it successfully invade new areas.

MATERIALS

- 20-foot-long piece of fine rope or twine, as well as a few shorter pieces with Velcro® to hold them together at the ends
- spray bottle
- Velcro® tabs
- Downy fluff (such as cotton batting, cotton balls, dandelion seeds, etc.)
- A jar of approximately 10,000 poppy seeds. There are 3,000 seeds per gram.
- A few slightly prickly or pointed implements such as wooden chopsticks with pointed ends
- "Armor" or shield (this could be a child's costume from a thrift store or something as simple as a piece of cardboard cut into the shape of a shield and covered with tinfoil)
- Telescoping pointer from a teaching supply store or tool supply
- Uninflated balloons
- A bag to fit all the above items into

BACKGROUND

Moving plants?

Plants don't have the ability to walk, fly, swim or crawl to new places like animals do, to escape danger, find food, or spread their offspring. However, they have evolved many rather amazing traits to protect themselves, grow, and reproduce.

Successfully invading species tend to have one or more of the following characteristics:

1. They reproduce quickly by producing many seeds.
2. Their seeds disperse far and quickly, by being airborne or adhering to fur or clothing (burrs).
3. Their seeds may remain viable for several years.

Dalmatian Toadflax
Linaria dalmatica

4. Seeds have high germination rates.
5. They grow quickly.
6. They are able to spread vegetatively (that is, through their roots or pieces of the plant).
7. They have deep roots (leafy spurge roots can reach 20 feet in length!).
8. They are not palatable to livestock and wildlife.
9. They are not susceptible to local diseases, parasites, herbivores, etc.
10. They are allelopathic – they give off chemicals that inhibit the germination or growth of other plants.

These are all admirable traits that make for successful plants, but they can cause problems for the other inhabitants of the new environment they invade, including humans. In this lesson, students can use a number of common items to demonstrate the traits that a weed they researched uses to help it survive and thrive in a new environment.

PROCEDURE

Students should be familiar with what weeds are and basic problems associated with them.

1. Begin the lesson by asking your students to imagine that:

You are seeds that have somehow been moved to a completely new area, where none of your kind live. Perhaps you've come from across the ocean on a ship or plane as a burr stuck on someone's clothing. Maybe you were in some hay or other animal feed. Or you were stuck in some mud in the tire of a vehicle that drove for thousands of miles before the mud was washed off by the rain.

You have left behind most or all of your natural enemies – animals, including insects, that like to eat you or the plants you grow into; a fungus that grows on you, making it hard for you to thrive; and any bacteria that infect you with disease. What's more, now you're in a spot where the plants that have grown here for thousands of years have been disturbed – some have been removed or harmed, leaving some bare ground. This could be a good chance to grow and have offspring – just what every plant wants! But there are still a lot of other plants in this new place. They want to live in the same soil as you do, take up the same space, use the same sunlight, and suck up the same water from the ground. What can you do to make sure you grow and flourish, and that your seeds are successful in creating new plants and increasing your population?

2. Have students brainstorm traits that might help plants invade a new area where the land has been disturbed, and make a list on the board.

3. Now have each small group of students pick a noxious weed in Montana and research its characteristics. They should make a list of the traits that help it succeed. You may want to continue the lesson another day at this point.

4. When students are finished with their plant research, explain that they are going to share their information about their plant with the rest of the class. However, instead of just telling about it, they are going to demonstrate what makes their plant successful. Explain that while plants can't move around like animals can, they have evolved other ways to help them escape danger and get the resources they need to survive and reproduce. Each species may have a "bag of tricks" to help them. Show them the bag of items from the Materials list and ask them to figure out ways to use those items, or any others they can find in the classroom, to demonstrate some traits that make their plant successful.

5. Give each group time to look through the items and brainstorm their demonstration. You might want to prompt or demonstrate some ideas for them. Possibilities include:

- 20' rope: root length in some species, such as thistle or spurge
- Spray bottle filled with water: allelopathic chemicals released to harm other plants
- Velcro® tabs: burrs
- Downy fluff: airborne seeds
- Jar of seeds: large number of seeds that can be produced by one plant of some species
- Prickly items: thorns to discourage herbivory
- Armor: tough plants, difficult to eat or kill
- Telescoping pointer/balloons: rapid growth

Student groups can take turns demonstrating a couple of their plants' traits to the rest of the class. At the end of these demonstrations, make a list on the board or discuss as a group the most common traits they found. Do many invasive species seem to have similar characteristics? Do some native plants have some of these same characteristics? Why aren't they considered noxious weeds? What keeps them from spreading and taking over like plants from other areas do? Can they think of other traits that might help plants outcompete other species?

Extensions

Have students research plants that are invasive in areas outside of Montana. Do these plants have some of the same traits? Are any of our native plants considered invasive elsewhere?

LESSON 19

Measuring the Competition

Grade level: K-5
Subject Areas: Biology, language arts, math
Duration: One 20-minute session to begin with, plus 10-minute sessions on several consecutive days to observe, measure and record plant growth.
Setting: Classroom
Season: Any
Conceptual Framework Topics: Species, classification, plant reproduction and growth, competition

OBJECTIVES

Students will understand how plants grow from seeds. They will be able to measure and record plant growth and know that different species of plants grow at different rates.

METHOD

Students grow 2 different species of plants from seeds. They measure and record their growth and compare the growth rates of different types of plants, and relate this to weed growth.

MATERIALS

- ✎ Some small treats (pieces of candy, cookies, or mini-toys); enough for each student, but with just a few in a small container to start with.
- ✎ **Lesson Data Sheet**
- ✎ Two different kinds of seeds that will sprout and grow at different rates, and that germinate easily. Good choices for fast-growing seeds are beans or peas, which also are large and easy to handle. Slower-growing choices include beet or spinach seeds. Or you might want to try a growing a mustard, *Brassica rapa* (also known as “Wisconsin Fast Plants” and used widely in school experiments) and a slower-growing native Montana plant such as *Gaillardia aristata* (blanketflower). See end of lesson for seed sources.
- ✎ Paper towels
- ✎ Small plant pots or paper or plastic cups (enough for each student to have 2) with holes poked into the bottom. (*Clear* plastic cups work nicely because students can also see and measure the growing roots.)
- ✎ Potting soil
- ✎ Sink or waterproof tray to have under plants when watering

BACKGROUND

Invasive plants are successful largely due to several evolutionary strategies that allow them to outcompete the native plants in their new environment. These usually include abilities to reproduce and/or grow rapidly. Producing lots of seeds, high germination rates, and rapid growth rates all help these plants get ahead of the competition for space, sunlight, water, and/or nutrients that other plants offer. Plant competition may take place aboveground, with stems and leaves, belowground, with roots, or both.

PROCEDURE

1. Begin by showing students the container with just a few treats in it (make sure there are not enough for every student). Ask them who would like to have one. Likely most or all will say yes! Now ask if there are enough for everyone. When they say no, ask what would happen if you put the treats in the front of the room and said whoever wanted one should take one. They will probably describe at least some kids rushing up to the candy and grabbing at it. Who will get it? Probably the fastest and/or biggest. Explain that this would be a *competition* for the candy. The students would compete to get there first. Ask if there are other ways they could compete for it. (They may mention such strategies such as tricking, tripping, or slowing their classmates.) Now show them the rest of the treats and explain, if necessary, that there are enough pieces for everyone. Ask if they would have to compete for one now. Explain that *competition only takes place when there are not enough of the items to go around.*

2. Now ask your students to imagine a small square of ground. (You may want to have students act this out.) There is only so much space, soil, and water in this square. Now imagine that there are lots of plant seeds in the soil from different kinds of plants. Do they think all those seeds can grow into plants in that small space? Why or why not? What happens when one plant shades another from getting sun? What about when one sucks up all the water in the soil? Explain that plants also compete for resources when there aren't enough to go around.

What do they think would allow some plants to do better than others? Brainstorm a list of traits or features that might allow one plant to get enough water, sun, etc. while others don't.

3. Now tell them that they are going to do an experiment to determine if different kinds of plants *germinate* (sprout) and grow at different rates. Give each student 2 seeds from the slow-growing plant and 2 from the fast-growing plant. Have them carefully examine the seeds and tell you what they notice about them. Explain that these are seeds from 2 different kinds of plants. Ask them to predict whether the seeds will all sprout at the same time or at different times. Now have each student take 2 seed pots and fill them most of the way with potting soil. With the pots in a sink or a waterproof tray, students should pour water into the pots until the soil is thoroughly wet. Now have them place one of each kind of seed in each pot, leaving about 1 inch of space between the seeds. (If using clear cups, place the seeds next to the side of the cup, so that the roots will be visible from the side). Write the type of seed on the cup or pot next to the seed so that when they grow they will be able to tell which plant is from which kind of seed. Have them wet paper towels thoroughly with water and place them over the seeds. This should keep the seeds moist overnight and help them germinate quickly.

4. Have each student put their name on their cup with a marker and leave the seeds overnight.

5. Each day, have students closely examine their seeds and write down their observations. They should note when each seed germinates (they will see it split open and stem and roots begin to emerge). After a seed has germinated, have the student carefully sprinkle more potting soil on top of the seeds, until they are covered completely with a thin layer of soil. Moisten the soil and leave the plants to grow in a warm, sunny spot. Don't forget to keep the soil moist, but not too wet!

6. When the stems have emerged from the soil, have students begin to measure and record their height every day, using the data sheet. If the roots are visible, also have them measure the roots from the outside of the cup, as best as they are able. Have them write down any other interesting information they notice as well. Continue this as long as you feel is valuable.

7. Discuss with your students whether one seed germinated and/or grew faster than the other kind. How do they think this might affect their ability to compete for resources? Did they notice differences in stem growth and in root growth? Why would we want to measure both? Could roots be involved in competition too? How?

Explain that many invasive plants or "weedy" species sprout and grow quickly, giving them a chance to use the resources that other plants need. That allows them to take over an area and crowd other plants out. Show them examples of fast-growing invasive plants in Montana, such as Canada thistle (*Cirsium arvense*), leafy spurge (*Euphorbia esula*), or sulphur cinquefoil (*Potentilla recta*).

Resources

Find native seeds and information at:
http://www.nativeideals.com
http://prairiekeepers.dbs.umt.edu/default.htm
http://www.mt.nrcs.usda.gov/technical/ecs/plants/pollinator/sources.html

Find Brassica seeds at:
www.carolina.com
www.enasco.com/farmandranch/Learning+Aids/Horticulture

Extensions

Have your students graph the growth rates of the different seeds. They can also plot the lengths of time to germination, and average the number of days to germination, or the sizes of the different plants at day 10.

Try the germination experiment under different conditions, such as leaving the soil fairly dry, or putting some in cool spots to see if this changes which seeds sprout and grow faster.

Try growing other kinds of seeds together. You can even collect and use your own weed seeds, but be sure to be very careful to dispose of the plants at the end so that they cannot continue to grow and reproduce! Remember that many invasive species can spread vegetatively, so they do not need to bloom to reproduce. Any plant parts and soil with seeds should be bagged before disposal in trash.

Explore other strategies invasive plants have for success. What kinds of traits would make plants grow, spread, and survive?

Name ____

Seed Germination Experiment

	Seed type:		Seed type:		Seed type:		Seed type:	
DAY	**Stem height**	**Root length**	**Stem height**	**Root length**	**Stem height**	**Root length**	**Stem height**	**Root length**
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								

Other interesting observations:

LESSON 20

Investigating Plant Competition

OBJECTIVES

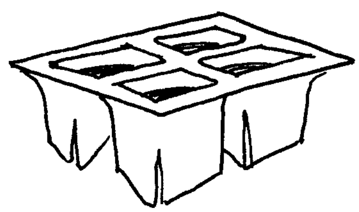
Students will understand that competition for limited resources may affect plant germination and growth. They will understand that this is one detrimental effect of invasive plants on native and crop plants.

METHOD

Students investigate interspecific plant competition for limited resources by germinating and growing seeds in the presence of varying numbers of other plants.

MATERIALS

- ✎ Planting flats with 2x2 cell inserts (Note: Using a clear, plastic lid, available at most greenhouses or garden supply stores, will help maintain moisture and maximize germination. It can be removed when plants are about 5 cm tall.)
- ✎ Potting soil
- ✎ Spinach seeds
- ✎ Alfalfa seeds
- ✎ Rulers
- ✎ Grow-lights or south-facing window
- ✎ Some small treats (e.g., pieces of candy or cookies); enough for each student, but with just a few in a small container to begin



BACKGROUND

Invasive plants are successful largely due to several evolutionary strategies that allow them to outcompete the native plants in their new environment. These usually include abilities to reproduce and/or grow rapidly. Superior seed production, high germination rates, and rapid growth rates all help these plants get ahead of the competition for space, sunlight, water, and/or nutrients that other plants offer. *Interspecific* (between species) plant competition may take place aboveground, with stems and leaves, belowground, with roots, or both.

Teacher Help: Your students should have a basic understanding of plant biology before beginning this lesson. For lower grade level classes you may need to introduce or review some of the scientific terms found in this lesson plan prior to beginning (i.e. *hypothesis* and *interspecific competition*).

Grade level: 6-12
Subject Areas: Biology, writing, technology
Duration: 1-2 hours, distributed across 2 or 3 class sessions, plus a few minutes daily to collect and record data for 8-10 days, and report preparation.
Setting: Classroom
Season: Any
Conceptual Framework Topics: Plant growth, ecological competition, invasive species ecology

(Adapted from the *Invasive Plants Taking Root in Alaska Curriculum*)

Extensions

Build on the concepts of competition by investigating the effect of nutrient availability on competition. Again, have students design their own experiment or follow the procedures in **Lab Sheet 2** for this lesson. Additional materials you will need: Miracle Gro® water-soluble fertilizer (24-8-16)

Have your students research competitive strategies of invasive plants in Montana.

PROCEDURE

1. Have your students set up and carry out the experiment using the instructions on the lab sheets. After they have completed the lab, have them summarize their information and address the questions.

2. Lead a class discussion on what they observed and see if they come up with the ideas of plants competing for resources and affecting growth. To encourage full understanding of how competition works, show students the container with just a few treats in it (make sure there are not enough for every student). Ask them who would like to have one. Likely most or all will say yes. Now ask if there are enough for everyone. When they say no, ask what would happen if you put the treats in the front of the room and said whoever wanted one should take one. They will probably describe at least some kids rushing up to the candy and grabbing at it. Who will get it? Probably the fastest and/or biggest. Explain that this would be a *competition* for the candy. The students would compete to get there first. Ask if there are other ways they could compete for it. Now show them the rest of the treats and explain if necessary that there are enough pieces for everyone. Ask if they would have to compete for one now. Explain that ***competition only takes place when there's not enough of the resource to go around***.

3. Can your students relate this to what they observed with their plant experiments? What kinds of resources might plants compete for? Brainstorm possible ways plants might outcompete others; discuss adaptive strategies such as fast growth and reproduction.

An alternative strategy to this lesson would be to first introduce the concept of competition with the candy demonstration. Then ask students to come up with some ideas for how to investigate whether plants inhibit seed germination and/or growth in other plants. Allow them to design and set up their own experiments with your guidance, or give them the student lab sheets and go over the procedures with them.

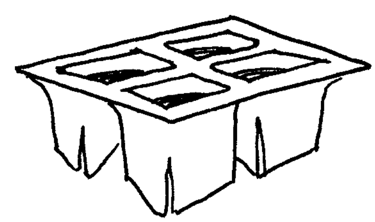
STUDENT LAB 1

Plant Competition

Plants have adapted a variety of strategies to compete with nearby plants when they have the potential to use resources in short supply. Some plants germinate very early in the spring to get ahead of neighboring plants. Some may grow very quickly to reach soil, water or sunlight first, or grow long, deep roots to obtain water and nutrients. How do you think invasive plants perform as competitors?

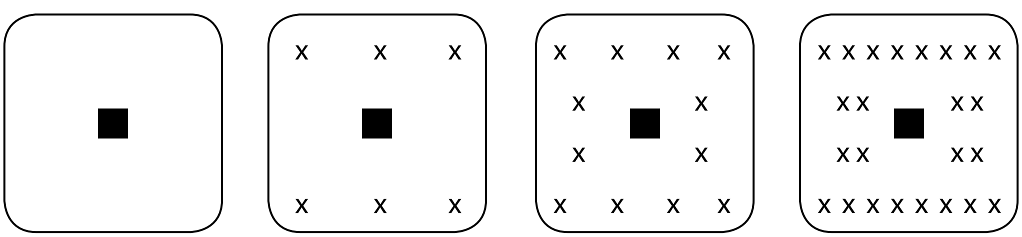
In this experiment you will test effects of increasing competition on your target plant.

DAY 1



1. Obtain two 2x2 cell inserts for planting and fill to top with moistened potting soil. Make a shallow (½") indentation (a pencil eraser works well) in the middle of each cell to plant the seeds. Carefully drop two spinach seeds in the indentation. This will be your "target plant" and will represent the native plant under competition for this lab.

2. In three of the cells, place additional, evenly spaced indentations around the target for planting 6, 12 and 24 "invading" neighbors. One cell should have no neighbors and will be used to compare with those plants under competition.



■ Target plant (spinach) x - Invasive competitors (alfalfa)

3. Carefully drop two alfalfa seeds into each of the indentations and label each cell with your initials, date and number of competitors.

4. Barely cover with a small amount of soil, spray with water and place into a planting flat containing a half gallon (3.7L) of water. Place under growing lights if available (16h light) or by south-facing window. Soil should be kept fairly wet until plants have germinated and water should be added to the flat as needed.

5. Write a hypothesis about how the various seed densities will affect the growth of the target plant. Do you expect to see differences in growth among the different plants? What other kinds of observations or measurements could you make to determine whether or not the presence and number of other plants has an effect on plant growth?

Design a data table to hold your data. The data table should have a space for all the information you'll need to record to answer your question.

DAYS 3-15

6. Measure and record the height of the middle or target plant and record number of leaves. Also make notes about anything else you notice about the invasive neighbors or how the plants are growing.

7. Make your final observations and plot them on a graph.

8. Summarize the outcomes in a lab report. Address the following:

- Did the data you collected support your hypothesis?
- Which target plants would you predict to make the most seeds? Why?
- How does this experiment relate to the issues of native and invasive plant species?
- What would happen to the "native" plants if they had to compete with more and more invasives?

9. Write a conclusion that summarizes what you learned in this activity.

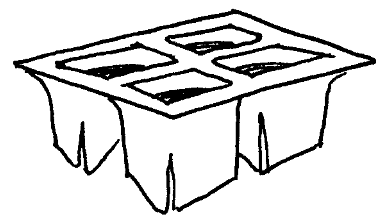
STUDENT LAB 2

Plant Competition Extension: Effects of Nutrition

One of the ways that plants compete with one another is for essential, but limited, nutrients in the soil. Plants need soil nutrients such as nitrogen and phosphorus to photosynthesize and grow. Many invasive plants have special adaptations that allow them to outcompete native plants in gathering nutrients. In this lab, you will investigate how the availability of nutrients can affect plant competition.

DAY 1

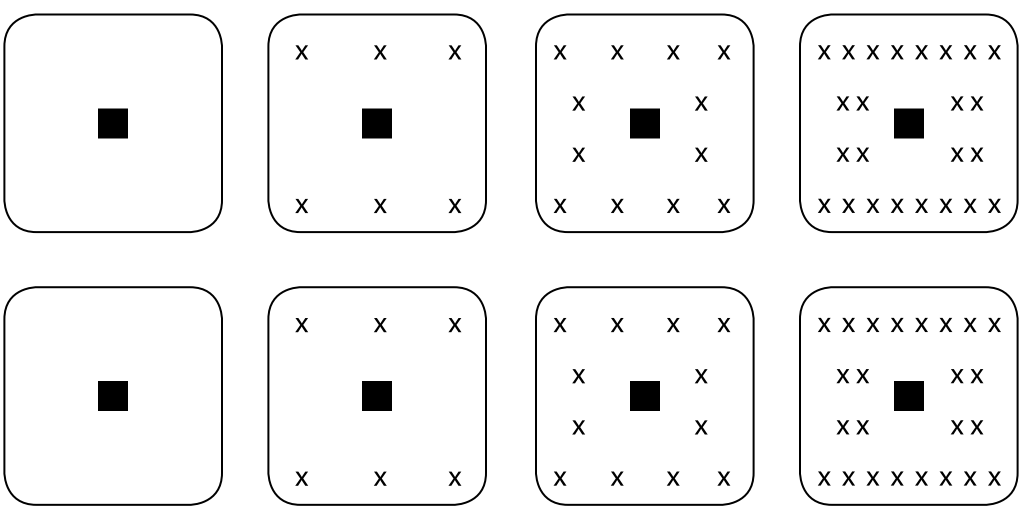
Prepare **TWO** sets of plants (8 cells) as in Lab 1 by:



1. Obtaining four, 2x2 cell inserts for planting and fill to top with moistened potting soil.

2. Make a shallow (½") indentation (a pencil eraser works well) in the middle of each cell to plant the seeds. This center plant will be your "target plant" and will represent the native plant under competition for this lab. Carefully drop two spinach seeds in the indentation.

3. In three of the cells, place additional, evenly spaced indentations around the target for planting 6, 12 and 24 "invading" neighbors. One cell should have no neighbors and will be used to compare with those plants under competition.



■ Target plant (spinach) x - Invasive competitors (alfalfa)

4. Carefully drop two alfalfa seeds into each indentation and label each cell with your initials, date number of competitors.

5. Barely cover with a small amount of soil, spray with water and place **ONE SET** into a planting flat containing a half gallon (3.7L) of water. **ONE DUPLICATE SET** should be set in a separate flat containing ½ gallon (3.7L) of dissolved Miracle Gro® fertilizer (24-8-16) solution (½ teaspoon).

6. Place under growing lights if available (16h light). Soil should be kept fairly wet until plants have germinated and water should be added to the flat as needed.

7. Write a hypothesis about how the plant densities will affect the growth of the target plant *with different amounts of available fertilizer.* Do you expect to see differences in growth among the different plants?

8. Design a data table to hold your data. The data table should have a space for all the information you'll need to record to answer your question.

DAYS 3-15

9. Measure and record the height of the middle or target plant and record number of leaves. Also make notes about anything else you notice about the invasive neighbors or how the plants are growing.

10. Make your final observations and plot them on a graph. Summarize the outcomes in a lab report. Address the following:

- Did the data you collected support your hypothesis?
- How did the plants grown with added nutrients compare to those grown without them?
- Does it appear that nutrients were limiting the growth of the target plant? What about the competitors (invasives)?
- Which target plants would you predict to make the most seeds? Why?
- What does your experiment have to do with the issue of invasive weeds and native or crop plants in Montana?

LESSON 21

Plant Warfare: Investigating Allelopathy

Grade level: 9-12
Subject Areas: Biology, writing, technology
Duration: 1-2 hours, distributed across 2 or 3 class sessions, plus a few minutes daily to collect and record data for 8-10 days, and report preparation.
Setting: Classroom
Season: Any
Conceptual Framework Topics: Plant competition, allelopathy, invasive species ecology

OBJECTIVES

Students will understand the concept of allelopathy and how it affects plant germination and growth. They will understand how allelopathy helps invasive plants outcompete native plants.

METHOD

Students experimentally test the effects of plant extracts on seed germination by comparing germination rates of seeds bathed in extract to those in water.

MATERIALS

- ✎ Seeds (radish, spinach, and lettuce)
- ✎ Petri dishes and filter paper
- ✎ Plastic wrap or parafilm
- ✎ Disposable pipettes and scissors
- ✎ Beaker (50 mL or larger)
- ✎ Distilled water
- ✎ Grow-lights or south-facing window
- ✎ Blender (1 for each different type of extract used)
- ✎ Cheesecloth
- ✎ Scissors
- ✎ Graduated cylinder
- ✎ Balance and weights (grams)
- ✎ Ruler
- ✎ Funnel
- ✎ Flask
- ✎ Samples of vegetation such as spruce, hemlock, garlic, fir needles, fresh tomato, fresh cucumber, alfalfa sprouts, or knapweed or hawkweed

If growing alfalfa for extract:*

- ✎ Planting flats with inserts
- ✎ Potting soil
- ✎ Alfalfa seeds

*NOTE: You can grow your own alfalfa sprouts in the classroom or buy them in the grocery store.

BACKGROUND

Although plants cannot move around and have no teeth or claws, they still have very effective weapons with which to wage war against their neighbors. Have you noticed that few plants grow underneath pine trees, Taxus bushes (yews) or some other species? These plants compete successfully for resources such as water, sunlight, and soil nutrients by keeping other plants away through the production of chemicals that inhibit the germination and/or growth of other plants around them. This is one adaptation that can give invasive plants, such as knapweed, an advantage over many native and crop plants.

Your students should have a basic understanding of ecological competition for resources and seed germination before starting this lesson.

(Adapted from the *Invasive Plants Taking Root in Alaska Curriculum* and the *Cornell-Boyce Thompson Institute for Plant Research Curriculum Program*)

Extensions

Have your students research allelopathy in invasive plants listed as Noxious Weeds in Montana.

Some of the students in the class can experiment with the concentration of the plant extract added to the Petri dishes. Have them label their beaker "2X" and increase the amount of plant tissue to 40 grams. Dilute the tissue in 100mL of distilled water. This will give them 2X the ratio of tissue/solvent utilized by the other group to start and enough to make a dilution.

Additional materials:

- Volumetric pipettes for transferring 50mL
- Glass stirring rods

To prepare the dilution:

1. Add 50mL of distilled water to three, clean beakers that are labeled 1X, 0.5X and 0.25X.

2. Use a volumetric pipette to transfer 50mL from the 2X plant tissue preparation to the 1X beaker.

3. Mix with a clean glass stirring rod and transfer 50mL of the 1X to the 0.5X. Mix and repeat to make the other dilutions. There should be 100mL in the 0.25X dilution when complete. **A clean pipette and stir rod should be used for each transfer.**

4. Prepare 5 Petri dishes with either spinach, radish or lettuce seeds as above. Pipette 10mL of each solution to the 4 dishes that are labeled with corresponding concentrations.

One dish should get only clean, distilled water to serve as a control.

PROCEDURE

Begin by asking your students how animals might compete for and defend resources in short supply, such as food or living space. Responses may include fighting or driving off competitors. Now ask if they think plants do the same things. Brainstorm possible ways plants might outcompete others; discuss adaptive strategies such as fast growth and reproduction, and explain that plants also engage in "chemical warfare." Tell them they are going to investigate whether some plants inhibit seed germination and/or growth in other plants. See if they can come up with some ideas as to how this might be done. You may want to brainstorm some possible plants to use for extract, and/or let them choose from the plants listed in *Materials*.

Give students the student lab sheets and go over the procedures with them.

After students have completed the lab, ask them to summarize their information and address the questions. As a class, discuss *allelopathy* and make sure they can agree on a definition as they compare the group data together as a class.

To grow your own alfalfa for extract:

1. Fill one flat of 2x2 cells to the top with potting soil. Plant with approximately 10g of alfalfa seeds that are spread evenly across the surface. Moisten the soil by placing a half gallon (3.7L) of water in the bottom of the planting flat. Water will wick upward into the soil. Sprinkle a small amount of soil over the seeds and mist with water. Keep soil very moist until plants have germinated and are beginning to grow. Place under grow lights or a well-lit area. Let them germinate and grow for 12 days.

2. Harvest alfalfa sprouts by clipping off stems at the soil surface.

Plant Warfare: Investigating Allelopathy

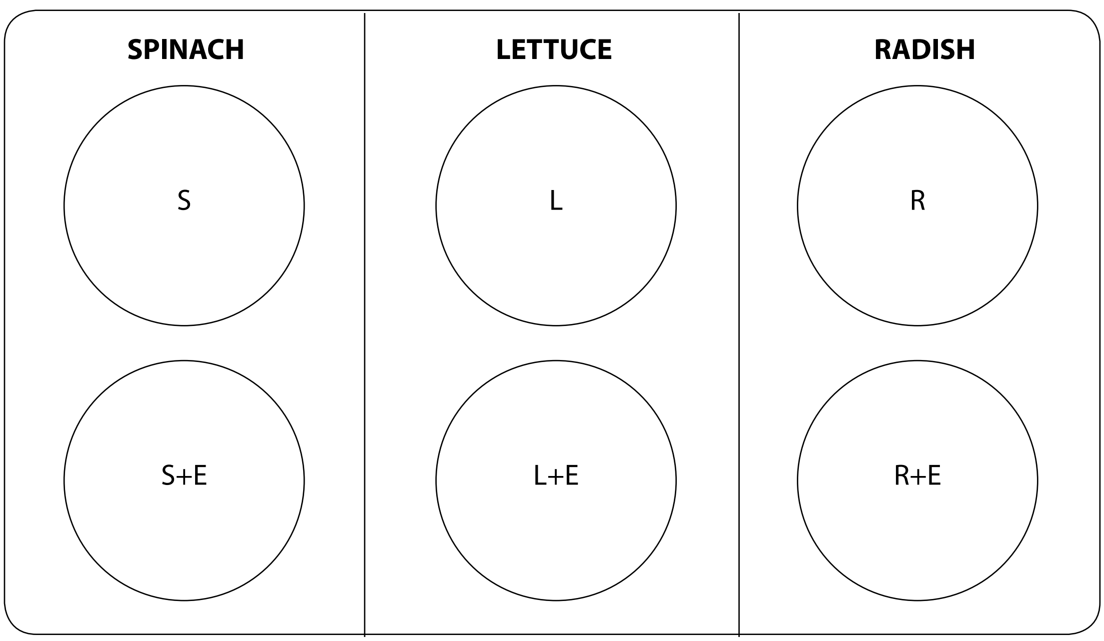
In this lab you will prepare an extract from plant tissues and test its ability to affect seed germination. For this exercise, the seeds of three different plants (radish, spinach and lettuce) will represent native plants and you will test the *allelopathic* effect of other plants on their germination.

1. Determine which plant material you will test for allelopathy. If necessary, use scissors or knife to cut one type of vegetation into small pieces before putting it into the blender. Weigh out 25 grams of vegetation.

2. Add 75 mL of distilled H2O for every 25 grams of plant material placed in the blender. Blend for 1-2 minutes. Let this sit overnight. This is enough for three different groups.

3. Filter the plant extract with cheesecloth and funnel. Discard the plant material from the funnel.

4. Each group should set out six Petri dishes and label as follows: S, S+E, L, L+E, R and R+E, (E= Extract) Petri dishes should be lined with filter paper or a single sheet of paper towel.



5. Evenly distribute 20 seeds of radish, spinach and lettuce into each corresponding labeled dishes.

6. Use separate pipettes to water each dish labeled (+E) with 10mL of the plant extract and each of the other dishes with distilled water. Be careful to use a different pipette for the extract and the distilled water so as not to contaminate the dishes with the wrong liquid.

7. Cover each with plastic wrap or parafilm and place under grow lights or a well-lit area.

8. Predict which seeds will have the highest rate of germination. What other kinds of observations or measurements could you make to determine whether or not the plant extract has an effect on seed germination? Design a data table to hold your data. The data table should have a space for all the information you'll need to record to answer your question.

9. Make daily observations of the seeds for about 10 days and note the number of seeds germinated (seed coat broken). Also observe and record data on the seedlings' appearance as they emerge (i.e. color, root and shoot lengths, etc).

10. Summarize your data by preparing a graph of the number of seeds germinated over time. Calculate the percent of germination:

 # seeds germinated per dish / total number of seeds per dish (20)

Summarize any data you collected on seedling size as well. Write a lab report to share your findings. Address the following:

1. Name the dependent and independent variables in this experiment.
2. How does what you learned relate to plant competition and invasive species?
3. Can you find information on invasive plants in Montana that use allelopathy to outcompete native plants?
4. Can you think of beneficial ways to use this information?
5. How would you improve this experiment if you did it again?
6. Write a conclusion that summarizes what you learned in this activity.

LESSON 22

Who Drank All the Water?

Grade level: 4-8
Subject Areas: Biology
Duration: 30 minutes
Group Size: Class
Setting: Classroom
Season: Any
Conceptual Framework Topics:
Plant water use, competition, Impacts of invasive plants

OBJECTIVES

Students will understand how a noxious weed, saltcedar, uses tremendous amounts of water, affecting other plants and people.

METHOD

Students estimate how much water a saltcedar tree can use in a day and then use jugs to fill a container representing a fraction of the actual amount. They use different lengths of twine to represent root lengths in saltcedar and native willows, to explore how saltcedar can exploit water sources far beyond the reach of native plants.

MATERIALS

- ✎ One or more 1-gallon milk or juice jugs (clean and empty)
- ✎ A larger container or containers that can hold 20 gallons total (NOTE: These will be filled with water, so you should be able to easily empty them after the lesson. Remember that water is heavy—8 lbs. per gallon—so you should be able to either drain them, lift them, or do the lesson outside where you can simply tip them over and let them empty onto the ground. 5-gallon buckets are probably the best choice in a classroom setting.)
- ✎ Water source for filling jugs
- ✎ 10-ft-long twine, string or rope
- ✎ 100-ft-long twine, string or rope
- ✎ Masking tape or duct tape

BACKGROUND

Saltcedar or tamarisk *(Tamarix ramosissima)* is an attractive deciduous tree (or shrub) with long slender branches and deep pink flowers. It is long-lived (50-100 years) and grows to 6 to 26 feet (2-8m) tall. The branches often form thickets many feet wide. Saltcedar is native to Eurasia. Saltcedar has become extensively established in the southwestern United States and Mexico. It extends north to Massachusetts, Indiana, Missouri, Kansas, Colorado, Nebraska, and Oklahoma. Stands of saltcedar occur in Oregon, Idaho, Montana, Wyoming, and South Dakota. Experts now estimate that saltcedar has infested more than 3.3 million acres in the western United States. It is believed that nurserymen on the East Coast made the first introduction of saltcedar to North America in 1823. It was planted as an ornamental in the western U.S., but by the 1870s, it was reported to have escaped cultivation.

In the Great Plains, saltcedar is common along streams, in low undrained areas, and around lakeshores, and is occasionally found on dry hillsides. Its roots may penetrate soil 100 feet to reach water. It has a wide range of tolerance to saline and alkaline soil and water. Saltcedar occurs from below sea level to more than 7,000 feet (2,134 m) in elevation.

Saltcedar is a very great consumer of water: a single large plant can absorb 200 gallons of water a day. This can lower ground water levels, dry up springs and wetlands, and lessen the water yield of riparian areas. Saltcedar's dense roots can slow down stream flow, increasing deposition and sediments along the riverbank. This can lead to saltcedar colonization further into the floodplain, widening the riparian zone, resulting in severe reduction of stream flow or even rechanneling. On the other hand, saltcedar root systems can also lead to flooding by choking the watercourse.

Saltcedar, like many other invasive plant species, has a great reproductive capability. A mature saltcedar plant can produce 600,000 seeds annually, and has the ability to flower during its first year. Seeds are easily dispersed by wind and water, and severed stems and shoots of saltcedar readily root in moist soil. The plant's ability to exploit suitable germinating conditions over a long time period gives saltcedar a considerable advantage over native riparian species.

A very rapid grower, saltcedar can grow 9 to 12 feet in a single season. Under drought, saltcedar survives by dropping its leaves and halting growth. Additionally, its seedlings are very resistant to drying. Under flooding, it can survive immersion for up to 70 days. Mature plants can resprout vegetatively after fire, flood, or treatment with herbicides and can adapt to wide variations in soil and mineral gradients. Saltcedar also deposits salt above and below the ground, forming a saline crust inhibiting other plants from growing in its vicinity. In addition to outcompeting native species, this also enables the saltcedar to cope with high concentrations of dissolved solids.

Saltcedar is difficult or impossible to kill by burning, drought, freezing, hypersalinity, prolonged submersion, or repeated cutting at ground level. However, it can possibly be controlled through a combination of methods.

Because saltcedar can very effectively resprout from roots or cut stems, simple removal of the plant is largely unsuccessful. Cutting or burning followed by herbicide application to the stump has been shown to be effective. Research has indicated that approximately a dozen insect species are available that might be useful in fighting saltcedar, but none are presently available.

PROCEDURE

Before beginning the lesson, review with students how water moves through plants (a good lesson to help with this can be found at: **http://www.lessonplanspage.com/ScienceExCanWaterTravelThroughPlantStemsMO68.htm**).

1. Tell your students they are going to learn about a small tree that was sold in plant nurseries in the U.S. starting almost 200 years ago and continued to be sold up until a few years ago. It became illegal to sell it because it has taken over and invaded so many places on its own that it has become a major pest and a noxious weed. Now it is growing in the eastern part of Montana, among many other places in the west, and causing lots of problems.

Give them some of the background information about saltcedar, but don't tell them how much water it uses—just that it uses a lot. Ask them to give you some examples of problems this might cause in places where water is not very abundant, such as Montana.

2. Show them the 1-gallon jug(s) and ask them how many jugs full of water they think a saltcedar tree can "drink" in one day. Write down the estimates on the board. Then have students begin to fill the jug(s) and empty them into the larger containers, keeping track of the number of jugs full of water and telling them that this will represent the amount of water a single saltcedar tree can use in one day. If they think they have reached the amount, tell them to keep going until 10 or 20 gallons have been emptied. Do they think that is enough? Explain that they would have to repeat filling the containers 10 times to reach the amount used by one tree in one day. Did anyone guess that much?

3. Discuss what kinds of problems they think that could cause for other plants, wildlife and people in the area where these trees invade.

4. Have two students stand at the water containers; one will be a saltcedar plant and the other a willow, a native plant that would naturally grow in the kinds of areas (streamsides, etc.) where saltcedar invades. Ask what will happen when the saltcedar uses all the water out of the water source. What will the plants do? Hand one end of the 100-ft twine to the "saltcedar student" and explain that this represents its roots. Have another student take the roll of twine and walk away until they have reached the end. Now have the "willow student" take the 10-ft roll. Roll out the 10-ft roll and have your students observe where it ends.

5. Discuss with your students what the implications are for the native plants and the saltcedar. How about humans using the water for a well or irrigation? What other animals might be affected? (Fish and other wildlife that might depend on a stream or the plants that grow around it.)

Extensions

Have students research the spread of saltcedar in Montana (see Resources section of guide for suggestions).

Have your students experiment to study transpiration and water loss in plants, using the excellent lesson from NSTA: *Thirsty Plants in Arid Places* **http://www.nsta.org/publications/article.aspx?id=Z349URi8cV4uSDyFBN2UzAZG6fGEErEhyZ/U9OYfQgA=**

LESSON 23

A Grain of Rice and a Hillside of Knapweed

OBJECTIVES
Students will be able to define "noxious weed," understand the awesome power of exponential growth, and be able to apply the concept of exponential growth to knapweed population increase.

METHOD
As students listen to a folktale that illustrates the importance of understanding exponential growth, they calculate the numbers of grains of rice as they increase in the story. They explore how exponential growth applies to knapweed reproduction and population growth.

MATERIALS

- ✎ *A Grain of Rice* by Helena Clare Pittman **OR**
- ✎ *One Grain of Rice: A Mathematical Folktale* by Demi **OR** view a version of this story online at the following University of Georgia mathematics education link: **http://jwilson.coe.uga.edu/EMT668/EMAT6680.F99/Martin/instructional%20unit/day4.exponential/excel/grainofrice.html**
- ✎ World map or globe
- ✎ 5 lb bag of rice
- ✎ Calculators (for older students you can use an Excel spreadsheet on computers)
- ✎ Paper
- ✎ Pencils
- ✎ **Worksheets** of rice calculations for 100 days
- ✎ Samples or pictures of knapweed/noxious weeds and native plants

BACKGROUND
Spotted knapweed (*Centaurea stoebe*) is an aggressive, introduced weed species that rapidly invades agricultural land, disturbed areas, and native grasslands. The weed is a prolific seed producer with 1000 or more seeds per plant. Seeds remain viable in the soil five years or more, so infestations may occur a number of years after vegetative plants have been eliminated. Spotted knapweed has few natural enemies and is consumed by livestock only when other vegetation is unavailable. The plant releases a toxin that reduces the growth of other species.

Grade level: 4-8
Subject Areas: Math, language arts/literature, social studies, science
Duration: 45 minutes
Setting: Indoors
Season: Any
Conceptual Framework Topics: Plant reproduction, invasive species ecology; invasive species spread by seed, plant populations and demographics

Adapted from the *Mount Jumbo Guide* for use in this guide with permission by author Shirley Atkins

Spotted Knapweed
Centaurea stoebe
© 2010, Nancy Seiler

Historical records indicate that spotted knapweed was introduced from Eastern Europe into North America in the early 1900's as a contaminant in crop seed. It is now established on several million acres of grazing land in the northwestern United States and Canada. Spotted knapweed infestations have been found in every county in Montana. The invasions can largely be traced to unintentional seed spread, such as in transported hay or on the wheels of vehicles. Spotted knapweed may remain for several years in a confined location and then spread rapidly to adjacent areas.

In this lesson we will introduce the idea of exponential growth in order to illustrate how rapid population growth of invasive plant species occurs when large numbers of seeds are produced, such as in spotted knapweed.

PROCEDURE

1. Locate China (if reading *A Grain of Rice*) or India (if reading *One Grain of Rice*) on a world map and introduce the story. Begin to read aloud *A Grain of Rice* by Helena Clare Pittman **OR** *One Grain Of Rice: A Mathematical Folktale* by Demi.

2. When the grains of rice begin to be delivered in the story you are reading, pause and distribute cups of rice, paper, worksheets and calculators to small groups. As the story progresses, ask the students to model the rice deliveries by counting grains of rice. The groups should also calculate the total grains delivered each day and chart their results. *For older students, an Excel spread sheet can be used to do the calculations on computers.*

3. When the process of counting amounts grows too great for the students, relieve them of these duties. Calculating should continue until the student calculators can no longer carry the appropriate number of place values as the story progresses and groups calculate the delivery amounts.

4. Whole group discussion: Discuss the story using open-ended questions. What did you like or dislike about this story? Why do you think the author chose this tale? What did this story teach us?

5. Discuss the math: How did you manage the task of counting? Calculating? What strategies did you use? How did you feel about this activity while you were doing it?

6. Although the worksheet only goes up to 30 days, ask for predictions about the numbers at 50 days, 75 days, and 100 days. If they have no clue, ask them to predict how many places the numbers will take and give higher/lower hints until they are in the right ball park. Display the answers as the numbers are discussed. Involve the class in reading the numbers aloud together, or dictate the numbers and allow students to attempt to record the numbers on the board. Give place value nomenclature as needed (i.e. quintillions, octillions, etc.).

7. With older students, discuss scientific notation and how that relates to estimation and rounding-off.

8. Making connections: Display pictures of knapweed and other noxious weeds of Montana as well as pictures of native plants of Montana. Compare and contrast pictures of native plant communities with weed-infested communities. Ask students to look up the meaning of "noxious" and create a working definition of "noxious weeds." Ask them how what they've learned about exponential growth might be related to invasive plants.

9. Ask the students to brainstorm in their small groups a way to record how many plants one spotted knapweed plant would generate in its eight year lifetime if five of its seeds become seedlings each year and grow to maturity. Allow time for discussion.

Extensions

Brainstorm ideas for delivering the appropriate quantities of rice without actually counting rice. Jump off into estimates and, for older students, exponential notation as a means of representing large numbers.

Teach ***Lesson 25: The Knapweed Hitchhikers*** to further develop understanding about reproduction and population growth in knapweed.

Teacher Help:

Answer Key for **How Many Grains of Rice Per Day** Worksheets:

1. **1**	21. **1,048,576**	41. **1,099,511,627,776**
2. **2**	22. **2,097,152**	42. **2,199,023,255,552**
3. **4**	23. **4,194,304**	43. **4,398,046,511,104**
4. **8**	24. **8,388,608**	44. **8,796,093,022,208**
5. **16**	25. **16,777,216**	45. **17,592,186,044,416**
6. **32**	26. **33,554,432**	46. **35,184,372,088,832**
7. **64**	27. **67,108,864**	47. **70,368,744,177,664**
8. **128**	28. **134,217,728**	48. **140,737,488,355,328**
9. **256**	29. **268,435,456**	49. **281,474,976,710,656**
10. **512**	30. **536,870,912**	50. **562,949,953,421,312**
11. **1,024**	31. **1,073,741,824**	51. **1,125,899,906,842,624**
12. **2,048**	32. **2,147,483,648**	52. **2,251,799,813,685,248**
13. **4,096**	33. **4,294,967,296**	53**. 4,503,599,627,370,496**
14. **8,192**	34. **8,589,934,592**	54. **9,007,199,254,740,992**
15. **16,384**	35. **17,179,869,184**	55. **18,014,398,509,481,984**
16. **32,768**	36. **34,359,738,368**	56. **36,028,797,018,963,968**
17. **65,536**	37. **68,719,476,736**	57. **72,057,594,037,927,936**
18. **131,072**	38. **137,438,953,472**	58. **144,115,188,075,855,872**
19. **262,144**	39. **274,877,906,944**	59. **288,230,376,151,711,744**
20. **524,288**	40. **549,755,813,888**	60. **576,460,752,303,423,488**
100. **633,825,300,114,114,700,744,351,602,688**		

Name ____

A Grain of Rice and a Hillside of Knapweed Worksheet

How many grains of rice were delivered each day?

1. answer: **1**	11.	21.
2. answer: **2**	12.	22.
3. answer: **4**	13.	23.
4.	14.	24.
5.	15.	25.
6.	16.	26.
7.	17.	27.
8.	18.	28.
9.	19.	29.
10.	20.	30.

LESSON 24

Hitching a Ride

Grade level: K-3
Subject Areas: Biology
Duration: 30-45 minutes
Setting: Indoors
Season: Any
Conceptual Framework Topics: Plant reproduction, plant populations and demography, invasion ecology, human factors

OBJECTIVES

Students will be able to identify some of the ways that weeds spread by seed.

METHOD

Students use toy vehicles in a model landscape to examine how seeds can be carried by vehicles, boats, and other means, promoting the spread of undesirable plants to new locations.

MATERIALS

- ✎ Samples of several local weeds including roots and seeds
- ✎ Plastic tub or wading pool with bottom covered with a layer of soil brought in from the local surroundings
- ✎ Water
- ✎ Small toy vehicles and boats with tread similar to ATVs, 4-wheel drive vehicles, mountain bike tires or other wheeled recreational vehicles
- ✎ Hiking boot (optional)
- ✎ Knapweed seedheads/seeds (can be collected in late fall/winter) and trash bags for safe weed disposal OR poppy or lettuce seeds and some celery or lettuce leaves to represent weed seeds and leaves

BACKGROUND

All plants reproduce. Plants reproduce by seed or vegetatively from plant parts. Most plants can reproduce from seeds, which are formed when flowers are pollinated. The spread of weeds along roads and trails is often caused by recreationists unknowingly, as seeds are caught in the tread of tires or boots and carried to new locations.

PROCEDURE:

1. Start the lesson by asking students to observe several types of weed seeds that can germinate and grow, in addition to weed plant material (i.e. small plants with roots) that can continue growing if moved from one location to the next.

2. Ask students to spread knapweed seeds and plant material (or alternatively use small garden seeds and vegetable leaves to represent weed seed and leaves) throughout the soil you have provided. Dampen half of the area to make comparisons between moisture conditions as observations are made.

3. Provide a variety of toy vehicles and ask small teams to take turns "driving" their vehicles through dry areas and through moist areas. Have them check their tires and other parts of the toys to see if any seed or plant materials have been

Extensions
Collect the materials that stick to the wheels and vehicle parts as the toy vehicles moved through the areas, and allow students to further investigate the material sticking to the vehicles to find seeds and other plant material. Use this as a springboard for students to design their own investigations using the toys, seeds and plant material, such as how does driving or walking through wet or dry soil, or sand vs. mud compare for transporting the most weed seed and material?

picked up. As an option, you can also demonstrate with a hiking boot how seeds and other plant materials can be picked up and carried in the tread of the boot to new locations.

4. Guiding the discussions with the following questions may help students discuss what is happening:

- Do you see anything sticking to your tires?
- Do the vehicles with big tread catch more or less on them than the ones with smoother tires?
- Compare the dry and wet areas – does one or the other result in more material sticking to the tires after you play with the toys?
- Can plants move this way in the real world? If so, how?
- If the plants and seeds are moved to places that do not already have these plants in them, what do you think will happen?
- Do all seeds turn into plants? Why or why not? What are some of the things that can keep a seed from becoming a plant?
- What do seeds need to grow?
- What are some other ways that seed and plant material can get to other places? (Possible answers: wind, water, animals, sticking to clothing, etc.)

5. If weed seed and material were used, the cleanup is critical so as not to inadvertently spread weeds. Use this opportunity to discuss with your students how they think they should dispose of the soil or sand used. Be sure all material is thoroughly washed off of the toys and boots, and disposed of in sealed garbage bags. As an alternative, use seeds and plant materials that are not a concern. Examples are listed in the materials section.

LESSON 25

The Knapweed Hitchhikers

OBJECTIVES
Students will be able to predict the spread of spotted knapweed over time based on seed germination rates.

METHOD
Students calculate the rate of weed spread from a recreational activity presented in a story, and discuss how weeds are spread and the role individuals can play in reducing weed spread.

MATERIALS

- ✎ Calculators
- ✎ Pictures of trails and roadside areas showing knapweed/noxious weeds
- ✎ **Knapweed Seed Production Chart**
- ✎ Optional: *Montana Noxious Weeds* booklet (see ***Resources*** section) or other field guides to the identification of Montana weeds.

BACKGROUND
Unintentional introduction of weeds has led to widespread infestations of invasive plants across Montana, with new invaders making their way into the state every year. See the ***Resources*** section of this guide for how to find more information on the history of plant introductions and the spread of noxious weeds in Montana.

PROCEDURE
1. Read aloud the following story, *The Knapweed Hitchhikers*

Jason loved to ride bikes. He especially loved to ride bikes over fast and bumpy terrain. He had saved all of his paper route money for two years in order to buy a new mountain bike. On the day that he went to pick up his brand new black bicycle with 24 speeds, he was already making plans for spending the rest of the day exploring the hills around his home.

Jason filled his water bottle and slid it into the holder, grabbed a couple of granola bars, and headed off on his shiny new bicycle. He had explored the surrounding area many times in previous years, but this was the first time that he had managed to get out on a bicycle this spring. As he rode up the narrow, winding road, he noticed that the plants in the ditches were just starting to sprout. He enjoyed riding down into the ditches and back up the other side, back and forth, up and down, like his own personal roller coaster. Later in the summer these roadside ditches would have tall, rough knapweed plants growing thickly along their sides, making this kind of riding

Grade level: 5-8
Subject Areas: Math, science
Duration: 30 minutes
Setting: Classroom and field site (optional)
Season: Spring, Summer or Fall if visiting field site
Conceptual Framework Topics: Seed dispersal, plant invasion in disturbed sites

Lesson used with permission from Shirley Atkins, developer of the *Mount Jumbo Education Trunk*, Missoula, Montana.

uncomfortable and dangerous. So he was glad for the unexpected opportunity. He couldn't help but yell now and then for the fun of it. YEEEEEESSSSSSS!

As Jason rounded the bend in the road, he was surprised to notice freshly plowed ground cutting into the hillside. He had no idea anyone was going to build a road in this area. He quickly turned his bicycle and started up the soft dirt track. This was just he kind of riding he liked most. Of course, going uphill wasn't as fun, although his new gears did help, but the ride down would be AWESOME. What Jason didn't realize when he started up the dirt track, was that some of the mud off his tires from riding the ditches was dripping off onto the newly plowed road. Jason's knobby tires held knapweed seeds mixed into the mud. By the next year, most of those seeds would sprout and grow, giving knapweed a foothold in a new area.

2. Explain the following to students: A knapweed plant can produce 1000 seeds or more in one year, and a seed can remain viable for up to 7 years, waiting for just the right conditions in order to germinate and become established. The number of seeds that germinate, or sprout, and become mature plants to reproduce can vary widely depending on the environment in which they are found.

Now develop a strategy with the class for calculating how many knapweed plants Jason "planted" over an eight year period if in the first year only one seed sprouted and grew to maturity, and if each mature plant then produced five more plants per year. The following chart can be used to record the results (this can be done as a class, in small groups, or individually). Make a guess as to how many places the answer will have before you calculate.

3. Discuss the results, and follow with a discussion on the conditions that are favorable for the spread of knapweed, and what conditions might slow down the spread of knapweed. What can you do personally so that you are not contributing to the spread of weeds?

4. Take a look at pictures or take a walk as a class to a disturbed roadside or trail and make note of any knapweed or other weeds and observe the conditions of the area. Take along the *Montana Noxious Weeds* booklet (see ***Resources*** section of this guide) or other field identification guide that include weeds found in Montana. Do you see anything that may have made this location susceptible to weeds? What can be done to manage areas like this in order to reduce the spread of weeds?

Name ____

KNAPWEED SEED PRODUCTION CHART

Year	# of Plants Bearing Seeds	# of Seeds/Plant that Germinate	# of Seeds that Germinate
1	1	5	
2		5	
3		5	
4		5	
5		5	
6		5	
7		5	
8		5	

TEACHER KEY KNAPWEED SEED PRODUCTION CHART

Year	# of Plants Bearing Seeds	# of Seeds/Plant that Germinate	# of Seeds that Germinate
1	1	5	5
2	1+5= 6	5	30
3	1+5+30= 36	5	180
4	1+5+30+180= 216	5	1,080
5	216+1,080= 1,296	5	6,480
6	1,296+6,480= 7,776	5	38,880
7	7,776+38,880= 46,656	5	233,280
8	46,656+233,280= 279,936	5	1,399,680

LESSON 26

Aquatic Invaders

Grade level: K-12
Subject Areas: Life science
Duration: 45 minutes
Setting: Indoors
Season: Any
Conceptual Framework Topics: Integrated weed management, weed control, plant ecology

OBJECTIVES

Students will understand the impact of aquatic invasive plants on ecosystems. Students will know how one of Montana's newest aquatic invaders, Eurasian watermilfoil, spreads into new environments and what can be done to help prevent its spread.

METHOD

Students demonstrate and discuss ways that Eurasian watermilfoil and other aquatic invasive species can be spread inadvertently to new locations during recreational and other activities.

MATERIALS

- Photo(s) of Eurasian watermilfoil
- Sink (or outdoor site for draining water)

For each group, distribute the following:

- 1 teaspoon dry dill weed (available in spice section of grocery store)
- 3 plastic tubs or buckets labeled **Lake**, **Pond** and **Wetland**
- 3 sheets of white paper
- Newspaper
- Magnifying glasses
- Small toy boats, twine or string, paper clips or washers, pencils, aluminum can, and other items for demonstrating human activity in our state's waters
- 2 coffee filters and a large funnel
- Cup

BACKGROUND

Aquatic invasive plants from sources outside of Montana are finding their way into our state's streams, lakes, rivers, and wetlands. Several species are currently found on the state's Noxious Weed List, including Eurasian watermilfoil. Eurasian watermilfoil (*Myriophyllum spicatum*) is an underwater aquatic plant believed to have been accidentally introduced in the 1940s to North America from Europe, where it is a widespread native plant. It is highly invasive in the northern U.S., aggressively competing with native plant communities. The mat-forming plants can clog propellers, impair swimming, restrict boating and fishing access, and affect water quality. By 2009, the only known infestations of Eurasian watermilfoil in Montana were in the Noxon Rapids area, where the plant was first discovered in the Cabinet Gorge Reservoir in 2007. In Montana it is now listed as a Category 3 Noxious Weed as well as a Priority Class 3 species in Montana's Aquatic Nuisance Species Plan.

Eurasian watermilfoil can spread from small plant fragments. It is tolerant of low temperatures and begins growing in early spring, outcompeting and shading native aquatic vegetation. The plant grows quickly until reaching the water surface, where it forms dense mats. Competition for sunlight and other resources results in reduced native plant diversity and abundance. Eurasian watermilfoil foliage supports few invertebrates, which are important food sources for fish and other wildlife. In addition, it expands into open water and creates habitat for non-native fish, increasing predation rates on native salmonids, which are open water species. Dense mats of Eurasian watermilfoil restrict recreational activities such as swimming, fishing, and boating, and the plant can clog water intakes and outflows and foul shorelines with decaying mats of vegetation.

Eurasian watermilfoil can look much like native species (see links under *Procedure* for photos). It can be identified by its whorls of four feather-like leaves around the stems with each leaf finely divided into paired leaflets, typically 12 to 21 pairs per leaf. The number of stems per plant increases as the plant ages. Each individual stem branches several times as it nears the water surface, creating a dense floating mat over the surface of the water. Dense Eurasian watermilfoil beds usually occur in water between 3 and 20 feet deep. The tops of the milfoil plants, both stems and leaves, often turn red in color. This species spreads by fragmentation, currents and waves, and overland via transport on boats, motors, trailers, fishing nets, and other gear.

Herbicidal control of Eurasian watermilfoil requires applying chemicals directly into the water. In Montana, applicators need a special permit from the Montana Department of Environmental Quality before applying aquatic herbicides. Eurasian watermilfoil is very sensitive to *2, 4-D*, but other plants in the treated area are impacted by the herbicide treatment as well. In weed removal as a control method, the risk of spread by stem fragments is high. Using fragment barriers around harvest operations and herbicidal control can prevent spread. Water drawdown followed by exposure to freezing temperatures for 96 hours will kill plants. This method has reduced infestations, but there are impacts to native vegetation and re-infestation can be rapid. There is also a biological control agent for Eurasian watermilfoil called the watermilfoil moth. However, it is not yet widely available.

Prevention is the most important management option for Eurasian watermilfoil in Montana. Mapping, monitoring, early detection and eradication are critical to prevention. If a new infestation is found, save a specimen and report the infestation to your County Extension or Weed Coordination office, or Montana Fish, Wildlife and Parks. To prevent spread, away from waterways remove all sediment and vegetation from boats, trailers, and equipment and wash thoroughly, including live wells. Dry all equipment. Never transfer water, vegetation, or animals between bodies of water.

PROCEDURE

Share a photo of the species Eurasian watermilfoil to the class while providing an overview of the threat of aquatic invasive plants and, specifically, Eurasian watermilfoil as one of our state's newest aquatic nuisance species (you can refer to information provided in the background section of this lesson). See the following web pages for photos and additional information:
http://agr.mt.gov/weedpest/Category3/EurasianWaterMilfoil.htm
http://www.seagrant.umn.edu/exotics/eurasian.html

Inform students that they will be conducting a small group investigation of how aquatic weeds like Eurasian watermilfoil can invade new locations from small plant fragments (The "weed" is represented by dill weed in this activity). *Teacher Note: For older students you may elect to have students design their own investigations.*

1. Fill three plastic containers about halfway with clean tap water.

2. Label the containers as follows: **Lake**, **Pond** and **Wetland**.

3. Add approximately a teaspoon of dry dill weed to the water in each group's **Lake** and mix the "weed" into the water.

4. Each group will next conduct water recreational activities in the **Lake**. For example, they will be boating (using a small toy boat), fishing (using a pencil with a string tied from its end and a paper clip or washer tied to the end); and placing "trash" into the body of water- such as an empty aluminum can, and pulling it out such as would happened during a lake cleanup day. You may want to provide materials representing other activities common to your local waters as well.

5. Each time a group removes an item from the water, ask them to move it directly to the **Pond** container, and then demonstrate the recreational activity again with each item.

6. Next, move the items from the **Pond** to the **Wetland**. Demonstrate recreational activities in the **Wetland**.

Extensions

Take a class field trip to a local pond, wetland or lake. Use ***Lesson 10: Know Your Neighbors*** from this guide or other format for study of the plants at this site. What would happen to this ecosystem if Eurasian watermilfoil were introduced? Have students research control methods for Eurasian watermilfoil and discuss the challenges of weed control in aquatic environments. How can we help ensure that aquatic invasive plants are not spread by our activities in and around Montana's aquatic areas?

7. Remove the recreational vehicles and gear and place each item onto clean white paper (over a stack of newspaper pages to absorb excess water). Using the hand lenses, ask groups to look for any remaining "weed" fragments on the white paper or anywhere on the recreational vehicles or other items. Pay particular attention to the insides of boats or other spaces that hold water – these show how boat bilges and engines can hold and carry weed fragments to new places.

8. In a sink (or outside) use a cup to slowly transfer water from the **Pond** through a coffee filter placed in a funnel and drain off the water. Similarly, pour the **Wetland** water through a separate coffee filter. Check for "weed" fragments in each filter, then compare how much "weed" was caught in each filter, and ask students to explain any differences in amounts *(Hint: The pond was exposed to recreational items first, and then the wetlands.)*

9. Compare what happened in this demonstration to the spread of aquatic invasive plants during recreational activities. Ask students: Is there anything we can do to stop the spread of Eurasian watermilfoil or other aquatic invasive plants?

Teacher Help: Wash boats and recreational equipment after use and before using them again including water skis, fishing poles, boots, float tubes, etc. Clean engines and bilges where water-carrying fragments of invaders may be stored before using again. Be careful that well-intended activities like weed removal and waterway cleanups do not contribute to the spread of invasives. European watermilfoil can even spread after being dried out.

LESSON 27

Schoolyard Plant Safari

OBJECTIVES

Students will be able to record basic scientific information in a field journal, and identify and record plant and habitat characteristics.

METHOD

Students will be guided in the use of journals to record scientific discoveries.

MATERIALS

- ✎ kNOweeds Journals (from ***Lesson 4: Making a kNOweeds Journal*** in this guide) or field notebooks
- ✎ **Schoolyard Safari Data Collection Sheet**
- ✎ Pencils
- ✎ Rulers
- ✎ Thermometer
- ✎ Field guides to plants and insects
- ✎ Digital camera (if available)

BACKGROUND

Biologists and resource managers collect information to help them learn more about organisms and natural processes they study. To help them recover potentially important information gathered in the field at some future time, they collect these field records according to a standard procedure or protocol. In this lesson, students will follow a similar approach to collect scientific information in the field, including recording the date, time of day, location, weather, a detailed description of the organism(s) and the surrounding habitat, and any other potentially relevant observations.

PROCEDURE

1. Take the class outside on a Plant Safari (this can be done in the schoolyard or other location), asking that each student make their own special plant discovery. Provide examples to students, such as evidence that something has been eating or otherwise using a plant they find. Students will use their ***kNOweeds Journal*** or a field notebook to record the information outlined in the **Schoolyard Safari Data Collection Sheet**, or they can use copies of the data collection sheet in the field and later insert or copy the results into their notebook or journal.

2. Back in the classroom have students share their discoveries and discuss why the information they recorded could be important as they continue their studies of plants. The class can identify the plants they found and label their drawings with the plants' scientific and common names.

Grade level: K-8
Subject Areas: Botany, environmental education, art, science inquiry skills
Duration: 1 Hour
Setting: Outdoors
Season: Fall, Spring or Summer
Conceptual Framework Topics: Plant identification, data collection, weed invasion

Extensions

Use the plant data collected to add the discoveries to the schoolyard map made in ***Lesson 28: Map Mysteries*** found in this guide.

Students can make homemade plant presses and press a plant specimen (see ***Lesson 10: Know Your Neighbors*** found in this guide) to go with their drawings or photos they make during the schoolyard safari.

Name ____

Schoolyard Safari Data Collection Sheet

1. Plant Discovery – Description

2. Draw your discovery here or take a picture!

3. What's the story behind your discovery?

    a. Is it a plant you have seen before?

    b. Does it have flowers?
    Does the plant have seeds on it?

    c. What color is it?
    What size?

    d. Where did you find it?
    Is there a water source nearby?
    Is the location sunny or shady?

    e. Are there others like it nearby?

    f. Is there any evidence that insects or other animals have used the plant?

    g. Is there anything else you observe that you find interesting about the plant?

4. Now answer these questions about your discovery. Circle one of each:

    a. Native ***or*** Exotic

    b. Planted ***or*** Arrived some other way

5. Circle the time of day.

early morning   late morning

noon   early afternoon

late afternoon   evening   night

6. What's the temperature outside?______________

Circle the kind of current weather
(circle all that apply):

bright sun   sunny   cloudy

light shower   rainy   heavy rain

light snow   heavy snow   snowstorm

LESSON 28

Map Mysteries

Grade level: 2-8
Subject Areas: Geography, life science, mathematics
Duration: Several class periods plus small group research time (can be done as homework)
Setting: Outdoors and Indoors
Season: Fall or Spring
Conceptual Framework Topics: Plant identification, weed management, citizen science and service, inventorying and mapping native and invasive plants

OBJECTIVES

Students will be able to create a map of a local area featuring predominant plant species (both desirable and invasive species).

METHOD

Students work in teams to create a map including the predominant plant species. Students will learn about the mapping process used by land managers in addressing invasive plant issues.

MATERIALS

- ✎ Five 60-foot lengths of string
- ✎ 5 measuring tapes
- ✎ 5 rulers
- ✎ 5 compasses
- ✎ 5 or more large sheets of graph paper
- ✎ Field journals (or notebook for writing outdoors) *Optional: Use journals made in* ***Lesson 4: Making a kNOweeds Journal*** *of this guide*
- ✎ Pencils
- ✎ Copy of a basic map of school site showing buildings (obtain from school principal or go to http://terraserver-usa.com/ for printable maps that feature schools)

BACKGROUND

Developing knowledge of your surroundings, or "a sense of place," is critical for building relationships that lead to effective stewardship of natural places and agricultural lands. Learning the mysteries of map-making can be so much fun that students may not even realize they are developing skills in map-reading, estimating, measuring and problem solving as they collect and record the data they need to create a schoolyard map. These skills are important for land owners and managers, as they are used to help address the spread of noxious weeds, wildlife habitat improvement, erosion, and other issues.

PROCEDURE

Explain to students that the class will be making a map of the schoolyard. As we add features to the map, we will record information about the vegetation that grows in the schoolyard.

1. For this activity, start with a map showing the dimensions of the schoolyard and school building(s). This usually can be obtained from the school and forms a "base map." Show students the base map and ask how they would add to it. What features will they show and how do they think distances could be measured? Show students maps of local areas. Display a range of maps in class.

Extensions
Follow up this lesson by having students work in groups to design a restoration project for a weed-infested area in the schoolyard or area close to the school. Measure and record the dimensions of the proposed area. Have students design the area using the measuring, mapping and plant identification skills that they have learned. Their designs can be used to propose an actual project to the school administration. *See **Lesson 30: Changes on the Land, Lesson 41: Pulling Together**, and **Lesson 44: The Restoration Cycle** from this guide for project ideas and resources.*

Have students research web sites for additional maps and compare the types of maps and what features are available in maps, such as topography, vegetation, roads and buildings, etc.

2. Next take the class outdoors and explore the schoolyard, focusing on the area for which you want to create a more detailed map. Have students take notes identifying or describing the plants, in addition to the location of rocks, sidewalks, and other features they see. You may want to suggest that they create a chart to help organize what they find and the locations.

3. Ask students to sketch a rough map of the area in their journal depicting the main features they identified. Ask students to estimate what the distances are between features such as a wall of the school, the play area, a sidewalk, a tree, etc. Ask students how they will obtain the actual data.

4. Demonstrate how to hold the tape measure to get distances, and so on. Compare actual distances with their estimates. Discuss how to map irregular shapes using string placed along the outer border and noting where the string changes direction and at what distance from the last change.

5. Create 5 small groups and assign each group a few specific tasks in the collection of class data, such as one group being asked to determine the perimeter of the schoolyard or the length and width of the sidewalk. Continue until you have data on the features to include in the map.

6. Hand out large sheets of graph paper, one per group. These will become schoolyard maps. You may want to include the school on this map already to get students started, and the use of a simple scale of 1:100. This would make 1 centimeter on the map = 1 meter on the ground. Have each group include the following on their maps: a north arrow, a legend, a scale, a date, and a border. Guide students in the use of the compasses to find locate north on the map.

7. Proceed to add desired features onto the maps, such as:
   - Vegetation types and, if possible, what species of plants and their estimated numbers. This includes weeds.
   - Location of irrigation or other water sources.
   - Shaded areas and sunny areas.
   - Hills, ditches, or other topographic features.

Update the maps as the school site changes with the seasons, new plants invade or are removed or planted, or features like play equipment are added, etc.

8. Ask students if there are weedy areas found and drawn on their map. If the school were to remove the weeds and restore the area, consider what the area would be like. Would it include trees, shrubs and flowers? If so, what species would be desirable to plant?

LESSON 29

Adopt-a-Nature Trail

Grade level: 2-8
Subject Areas: Biology, language arts, visual arts, technology
Duration: Three or four 30-minute sessions, plus travel time to field site if necessary
Setting: Classroom and an outdoor site such as schoolyard or a nearby park with native and non-native plants.
Season: Spring, Summer, Fall
Conceptual Framework Topics: Species, classification, identification, plant ecology, invasive species

OBJECTIVES

Students will know how to identify local plants and their status (native or non-native, invasive, etc.) and values. They will become skilled at sharing their knowledge with their community through a nature trail with plant labels and signs.

METHOD

Students learn about plants in their schoolyard or nearby neighborhood. They research their plant and make simple signs to label plants they identify, with information about the plant, to teach other students or members of their community about local plants, including invasive species.

MATERIALS

- ✎ Plant identification guides
- ✎ **Plant Information Sheet**
- ✎ Sign-making materials (use these or others you prefer): Cardboard, clear contact paper, markers, computer and printer, wooden dowels

BACKGROUND INFORMATION

An important part of science is communicating to others what you have learned. This communication can take many different forms. On many public and some private lands, visitors can learn about the environment through interpretive signs or nature walks, giving them the opportunity to see and learn about local organisms in a natural setting. These direct experiences help connect participants with the natural heritage of their local area. It also makes it more likely for them to remember what they have learned, and want to take part in the stewardship of local resources.

Montana has a wide variety of native flora, ranging from the vegetation of the moist old forests in the northwestern part of the state to the dry prairie grasslands in the east. Montana also has 34 plant species listed as noxious weeds. There are other species that show invasive tendencies, but have not yet colonized sites in Montana. Recognizing local, common plants is a first step in understanding the ecology of the landscape and the challenges faced in managing invasive weeds.

PROCEDURE

Ahead of Time: Students should be familiar with the basic terms related to weeds and plants. ***Lesson 10: Know Your Neighbors*** and ***Lesson 13: A Weed by Any Other Name***, from this guide can be used to introduce these terms .

1. Select a site such as your schoolyard or a nearby park or other public space where there is a variety of plant species (ideally native plant species and perhaps

some invasive weeds as well), and obtain permission to place small "interpretive signs" at plants on the site. You may want to make signs that will be in place for a long time, or you may want to make a temporary "display" of signs that will be removed after a determined amount of time. For example, if you do this activity in the spring, you may decide that signs will be removed at the end of the school year or the summer.

2. Visit the site with your students. Have each student or small group of students select a plant and identify it using a plant guide book or weed identification materials (see Resources section for ideas). Try to select plants that are along a path or all in an area that can easily be traversed from one plant to another.

3. Back in the classroom, have your students brainstorm ideas about what kinds of information they think would be important to learn and teach about their plant. List these on the board, and if you wish to have them use the Plant Information Sheets provided, have them copy that list onto their sheet.

4. Now your students are ready to research their plant. Have them use guide books and/or internet resources such as visit **http://montana.plant-life.org/index.html** or **http://plants.usda.gov** to gather the information they decided would be important.

5. Once they have researched and recorded their information, your class will need to decide how to present it on small signs that will be placed at the plants. You may want to have each student or team design a general sign format and have a contest to decide which one to choose. Or you can do it as a group, using the following questions to guide the process:

a. What shape should our signs be?

b. How big should our signs be?

c. Will they be printed or handwritten? How big should the writing be?

d. What color(s) will we use?

e. What materials will we make our signs from?

f. How will we protect them from rain?

Very simple signs can be made from flat cardboard, cut to dimension and covered with plastic sheet protectors or clear contact paper. Nail or tack these to dowels or flat sticks to place in the ground.

6. After your signs are completed and in place, have your students take another class, your principal, their parents, or other members of the community along the plant "path," with each student or group explaining what they have learned about their plant.

Extensions

Have students brainstorm ideas to reduce invasive plants and make their nature trail better for native or other desirable plants. Related lessons from this guide include ***Lesson 41: Pulling Together*** and ***Lesson 44: The Cycle of Restoration.***

Name ____

What I Want to Learn About My Plant:

COMMON NAME: ___________________________________

SCIENTIFIC NAME: _________________________________

IS IT (Circle all that apply):

NATIVE NON-NATIVE INVASIVE NOXIOUS

How is my plant important to my community? (Does if provide food, shelter, or another resource for local animals, including insects or birds? Is it used by people or livestock? If non-native, does it cause any problems for people or the natural world?)

What are some characteristics of my plant? (Does it grow fast or slowly? How does it reproduce? What kind of habitat does it like?)

LESSON 30

Changes on the Land

OBJECTIVES:
Students will be able to explain the reasons for monitoring a weed-infested site and the importance of monitoring on a long-term basis.

METHOD:
Students conduct a monitoring study of a weed-infested area using hula-hoops to outline their study plots. Students collect data on the distribution of native and invasive plants over time.

MATERIALS
✎ String
✎ Stakes
✎ Hammer
✎ Plant field guides, weed identification materials

For each small group, provide:
✎ Tape measure (at least 50' long)
✎ Hula-hoops (all of the same size; label each with a different number on a piece of tape)
✎ Paper
✎ Permanent marking pen
✎ **Hula-hoop Monitoring Study Worksheet** and **Study Data Chart**

BACKGROUND
Any plant growing where it is not wanted, especially where it becomes a nuisance because of its presence in large numbers or because of objectionable attributes, is considered to be a weed. Invasive plants, a more specific term than weeds, are unwanted plants that tend to grow aggressively in agricultural lands, home gardens, roadsides and other disturbed sites. Left unchecked, they can invade new areas and can have a significant negative impact on native plant populations and the ecological balance of the area. Some of these plants can cause allergic reactions or poisoning in livestock, wildlife or humans if contact is made or if they are eaten. The majority of invasive plants are exotic species which originate in other countries, spreading in Montana free of the natural competition and pests that limit their populations in their countries of origin.

Monitoring of vegetation allows professionals and citizens (including schoolchildren) to collect information on their local invasive species. This lesson provides students with the opportunity to learn about and participate in the monitoring of species distributions.

Grade level: 2-6
Subject Areas: Life science, mathematics
Duration: Two or more class sessions, ongoing study option
Setting: Outdoors/Indoors
Season: Fall, Spring
Conceptual Framework Topics: Weed management, monitoring

In this lesson we will use readily-available hula-hoops in place of PVC pipe meter square frames generally used by scientists to define areas for sampling.

PROCEDURE

Scout out a suitable weed-infested area containing native and invasive plants ahead of time. Review and make copies of the **Hula-hoop Monitoring Study Worksheet** and **Data Chart**. Gather the supplies listed in the materials section.

1. Explain to students that we are going to begin a project that will track changes in the balance of native plants and invasive plants in a "weedy" area. Scientists use a method called monitoring to track and measure changes in an area over time. This project could form the basis of monitoring a site about to undergo changes, such as weed control treatment.

2. Ask students: Why would it be important for us to monitor the vegetation in the weedy area?

Make a list titled **Why Monitor Weeds & Native Plants?**
Teacher Help: Organize student answers into the following reasons:

- *To test methods or treatments used.*
- *To measure population changes of weeds and native plants over time.*
- *To prevent the spread of weeds by detecting them early.*
- *To track and communicate to others about the status of the vegetation to help with management decisions.*

3. As a class, form questions and predictions about what will be observed in the area over time. Explain to students that it is important to decide what will be measured before setting out to monitor an area.
Make a list titled **What is Being Measured?**
Teacher Help: Organize student answers into the following categories for both weeds and native plants.

- *How many plants of each type are there?*
- *How healthy are the plants?*
- *How much area is covered with weeds?*
- *How do these factors change over time?*
- *What do we think will happen?*

NOTE: Additional questions and predictions can be made, but make sure they are measurable.

4. Determine the timeline for the project and a measurement schedule by asking: When are we going to begin to measure our area? How many times will we return over the span of the project and at what intervals? When will we end our monitoring study of the area?

5. Discuss and outline materials and methods. Explain to students that the next step is to agree on how we are going to measure changes and collect data that will help us answer questions.

6. The area of the study should be at least 50' X 50'. Mark off the area using string and stakes. Divide students into groups and have all students stand spread out around the outside of the boundary of the study area. A student from each group is given a hula-hoop (students will need to determine the area inside of the hula-hoop, this will be the plot sample size.) The group member with the hula-hoop should close their eyes or turn their back towards the study area and throw their hula hoop randomly into the stringed-off area. Use the spot the hula hoop lands on as the sampling plot for each group.

7. Fill in **Worksheet**.

8. Collect data using the **Data Chart**. Repeat data collection on a new sheet during each scheduled sampling period (as planned with this class example of a "long-term" monitoring project).

9. Have students discuss their questions/predictions after sharing the data with the entire class. By the end of the monitoring study, are they able to answer their questions? Do the data support their predictions? Why or why not?

Extensions

Public monitoring projects often rely upon volunteers for the collection of monitoring data. As a class, explore local options to help with a monitoring project in the community. If possible, invite a representative to come to the classroom to give the class an overview of the project. Volunteer on a selected project as a class, or invite interested students to volunteer for a monitoring project as part of an independent research project.

Hula-hoop Monitoring Study Worksheet

Group Members:____

Location of Study Site:____

Hula-hoop #:______________

Plot size (area inside of group's hula-hoop in cm):______________________

Monitoring Start Date:____________

Planned Monitoring End Date: ______________

1. Draw and attach to this sheet a map of the total area being monitored, and include an arrow indicating north on your map. Add to your map the location of your group's hula-hoop sampling plot.

2. Identify or describe the most prevalent plants and other features in your hula-hoop sampling plot.

3. Develop one or more questions you would like to address in this study. Example: Is weed species X increasing, staying the same, or decreasing over time?

4. How would you expect the study area to change over time if there is no weed control treatment or planting conducted? What about if there IS weed control and planting?

5. How can you use the hula-hoop plot class data to estimate plant populations in the larger study area? Is there a way to see how close the estimate is to the actual populations? If yes, how could it be done? Why don't scientists count the exact plant populations in most studies?

Hula-hoop Monitoring Study Data Chart

Copies of this sheet will be needed for data collection each time plot sampling occurs.

Group Members: ____

Date: ______________

Hula hoop #________

Plot size (area inside of group's hula-hoop in cm): ______________

Plant Name	Comments about plant	How many in plot?

Additional Notes:

LESSON 31

Virtual Survey of Invasive Plants

OBJECTIVES

Students will be able to understand the difference between a survey and a census, understand and implement different sampling techniques, and recognize that plants (including weeds) grow in specific niches or habitats.

METHOD

Students develop a weed sampling plan on a map of a park. They check the results of their sampling plan and calculate the area and percent of the park that is invaded by weeds.

MATERIALS

- ✎ Map of park (fictitious); attached
- ✎ Map of park (fictitious) that shows weed locations (for teacher); attached (you may want to copy this onto a plastic transparency to make it easier for students to quickly check their results with the key).

BACKGROUND

Many land managers are concerned about the spread of non-native, invasive plants (weeds) in natural areas. To be able to know whether or not weed populations are invasive, managers must first know where populations exist. Most areas are too large for conducting a census (i.e., complete count), so survey methods must be used. Surveys can tell you if and where species are present, and allow you to estimate how much of the total area is invaded. They don't tell you how many plants are present or how dense they are.

There are several such methods that can be used to survey an area for weeds. These include: (1) conducting a roadside survey, (2) surveying weeds along trails, (3) conducting surveys along transects (straight lines) that don't follow roads or trails, or (4) surveying in completely random locations. Each of these methods has potential advantages and disadvantages, and a sampling plan must consider these to get the most information possible to be able to know or predict where weeds are most likely to grow in the environment.

Grade level: 7-12
Subject Areas: Biology
Duration: 2 class periods
Setting: Classroom
Season: Any
Conceptual Framework Topics: Plant distributions, habitat, invasive species management, mapping and survey techniques

Contributed by Erik Lehnhoff, Center for Invasive Plant Management, Montana State University.

PROCEDURE

1. Explain to your students that they will be using a map of a fictitious area to explore how different methods of surveying an area can give different results on the distribution of invasive plants. The imaginative scenario is as follows:

- You have 4 days to sample the park area shown on the map.
- If you sample along the road, you can sample 50 squares per day.
- If you sample along a trail, you can sample 35 squares per day.
- If you sample along transects, you can sample 20 squares per day.
- If you sample with a totally random pattern, you can sample 10 squares per day.

Have students work in pairs or small groups to:

a. Choose their sampling method(s) and mark the squares on the map where they will conduct surveys.

b. Compare their map with the teacher's key to determine how many of the squares that they sampled had weeds.

c. Based on their findings, have them try to determine how much of the total area is infested with weeds.

2. When their calculations are complete, have them report to the rest of the class:

a. What method of sampling did you use?

b. How many of your sampled squares had weeds (list by species)?

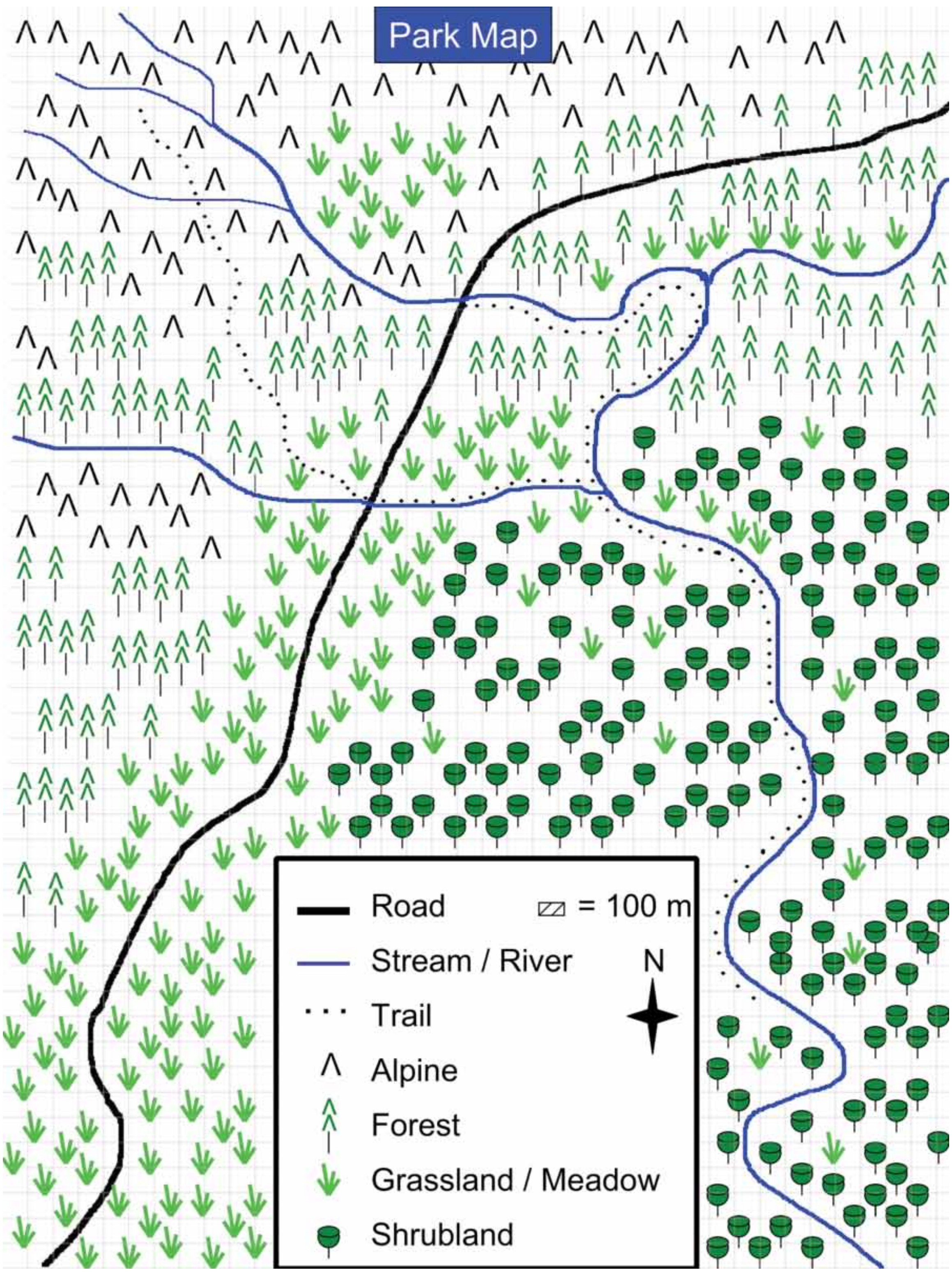
c. How much of the total park area (what percent) do you predict to be infested with each weed species?

Note: Students will very likely overestimate the area infested because, without knowing it, they make the assumption that all habitat is the same. For example, if they find a certain weed in 90% of the squares they sample along a road, then they assume 90% of ALL squares have the weed. The correct way to make the determination would be to find out what percent of each habitat type has weeds, find out what percentage of the park is each habitat type, and from that, calculate how much total area has the weed species. For example, the weed may have been found in 90% of roadside squares sampled, but only in 2% of grassland squares sampled. If the park is 1% road and 99% grassland, the total percent infested could be predicted to be:
$0.90 \times 1\% + 0.02 \times 99\% = 2.88\%$ (round to 3%).

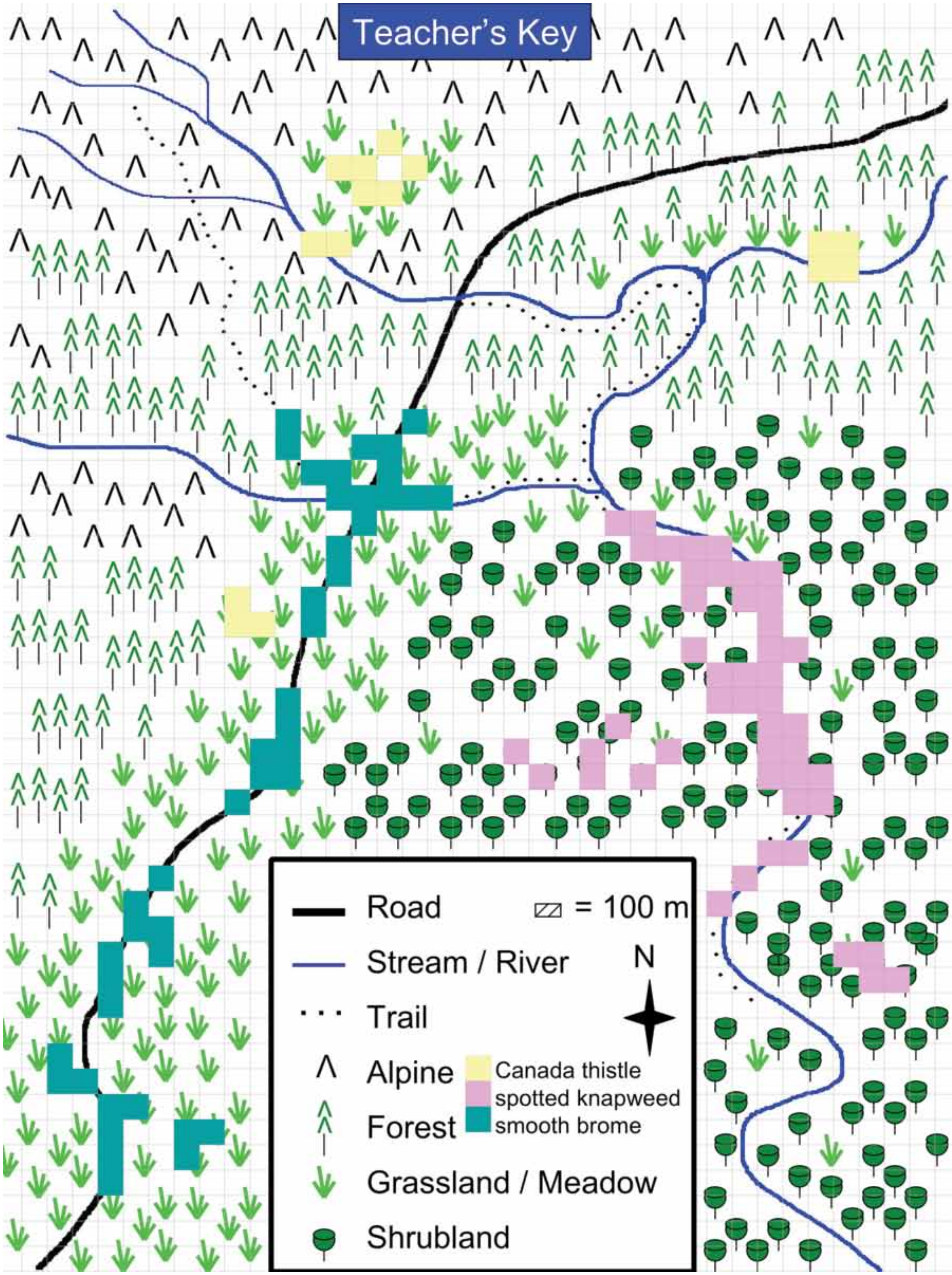
3. Discuss as a class:
   a. How accurate were their methods?
   b. Were some methods better than others? Why?

4. If students haven't come up with the idea that they need to sample based on different habitat types, prompt them to look carefully at the maps and see if they can figure this out. Have them calculate an infestation using this method.

Extensions
Have students use their understanding of sampling methods to set up surveys for invasive plants in a park, empty lot, or another accessible area near your school.



Park Map
Road
= 100 m
Stream / River
N
Trail
Alpine
Forest
Grassland / Meadow
Shrubland


Teacher's Key
Road
= 100 m
Stream / River
N
Trail
Alpine
Forest
Grassland / Meadow
Shrubland
Canada thistle
spotted knapweed
smooth brome

Teacher's Key to habitat areas and percent infested by weeds.

Note: Many squares may have more than one habitat type. For example, all squares along the road may be considered road habitat or some other habitat such as grassland/meadow or forest. Similarly, many squares along a river could be considered to be river, trail or some other habitat. When there are multiple habitats, use the following priority: Road ➜ Trail ➜ Stream/River ➜ any other habitat.

	AREA (number of 100m x 100m squares) and percent of each habitat in park							
	Road	**Trail**	**Stream/ River**	**Alpine**	**Forest**	**Grassland/ Meadow**	**Shrubland**	**Total**
Area	99	83	177	230	315	353	387	1,644
Percent of total area	6	5	11	14	19	21	24	100

	AREA (number of 100m x 100m squares) infested by weeds in each habitat							
SPECIES	**Road**	**Trail**	**Stream/ River**	**Alpine**	**Forest**	**Grassland/ Meadow**	**Shrubland**	**Total Area Infested**
Canada thistle	0	0	4	0	0	11	0	15
spotted knapweed	0	20	4	0	0	2	22	48
smooth brome	27	8	0	0	0	9	0	44

	PERCENT OF HABITAT INFESTED							
SPECIES	**Road**	**Trail**	**Stream/ River**	**Alpine**	**Forest**	**Grassland/ Meadow**	**Shrubland**	**Total Percent of Park Infested**
Canada thistle	0	0	2	0	0	3	0	1
spotted knapweed	0	24	2	0	0	1	6	3
smooth brome	27	10	0	0	0	3	0	3

LESSON 32

Weed Detectives: Surveying for Invasive Plants

Grade level: 9-12
Subject Areas: Biology
Duration: 3 class periods plus independent research time
Setting: Classroom and field site
Season: Spring, Summer or Fall
Conceptual Framework Topics: Plant distributions, habitat, invasive species management, mapping and survey techniques

OBJECTIVES

Students will understand how and why areas are surveyed to determine whether invasive plant species are present. They will be able to conduct early detection surveys.

METHOD

Students learn about noxious weed species in their area. They learn how to conduct early detection surveys for those plants. They practice recording data for the surveys on the school grounds before using them in the field to survey for local invasive species.

MATERIALS

- ✎ Maps of area to be surveyed
- ✎ **Invasive Plant Survey Data Form**
- ✎ **Invasive Plant Survey Summary**
- ✎ GPS Units (optional)
- ✎ Photos or guides to weeds (see below)

BACKGROUND

Scientists and land managers often collect data on the location and numbers of plants, including invasive species. There are several methods used to sample plants, and which one is used depends on a number of factors, including what you want to know and how much time you have to collect data. Two methods important in the study and management of invasive plants are surveys to identify where they occur, and sampling to determine how numerous or dense they are.

Surveys for invasive species are aimed at finding species as they invade an area (early detection surveys) or to determine which species occur in a previously unsurveyed area. Because the most effective management of invasive species occurs when species first begin to invade and populations are still small, early detection surveys can be extremely important. These surveys are not designed to determine the population size or density of plants. Such surveys can be completed with fairly minimal time and effort.

In this lesson your students will learn to conduct early detection surveys for invasive noxious weed species. kNOweeds ***Lesson 31: Virtual Survey of Invasive Plants*** will be helpful to prepare students for this lesson.

Houndstongue
Cynoglossum officinale

PROCEDURE

1. Select an appropriate area for your students to "adopt" to learn about and perhaps help manage invasive species (see kNOweeds ***Lesson 46: Invasive Plant Management: Plan to Action***). This could be a local city park, an empty lot, a stream corridor, a nature park or preserve. Contact the appropriate agency or organization to gain permission to conduct your studies and perhaps request advice and information. You may be able to obtain maps from one of these sources.

2. Explain to your students that it is often impossible to check every part of an area for invasive species due to time and resource constraints. Ask how they think they could best determine what invasive species occur in an area such as a park, empty lot, forest, or other site of interest. Discuss the idea of collecting data in a portion of the site to get a suggestion of what the entire area is like.

3. Have your students learn to identify invasive species in your part of Montana. You may want to direct them to the following sites:
http://www.weedawareness.org/weed_id.html
http://mtwow.org/Weed-ID.html
Photos of weed species at the time of year of your survey will help them in the field.

Talk to a local land manager to find out which species you might want to focus on, such as newly invading species or others whose presence in the study area may be unknown. It may not be feasible to try to record all the noxious weed species if your area is heavily invaded.

4. Decide on a survey method (including survey routes, lengths, locations), taking into consideration the type of habitats the species you want to focus on occur in, whether they tend to colonize disturbed sites, etc. Mark the sites you will survey on a map of your study area and give each one an identification number (survey route number). Divide up the survey sites among the students. You will probably want to have them work in small groups or pairs, with each group responsible for a section of trail or roadside or a sub site of the area. Make sure each group has a map of their portion of the study area. You may want to have them sketch a map, roughly to scale, of the survey area on the back of the data sheet.

5. Have your students practice filling out the data forms and mapping locations using plants on the school grounds as substitute (or real!) noxious species. Make sure they understand how to estimate patch size and make accurate locations on a map.

6. Have students walk the survey sites and record data for the species you are focusing on, using their **Invasive Plant Survey Data Form** and their map. If you have GPS units, use them to help map the locations. **Make sure that students fill out a form even if they didn't find any of the species on their survey route.**

7. Emphasize to students the importance of cleaning shoes and clothing of any seeds or other plant parts after completing their surveys.

8. As students complete their surveys, have them fill out their portion of the **Invasive Plant Survey Summary Form** as well as the locations on a map of the entire area. You may want to have a map for each plant species surveyed, or color codes for each species if there aren't very many. Have them number each patch they record (e.g., they could record *Centaurea stoebe* patches as CM1, CM2, etc.).

9. Based on the data your class collected, discuss the condition of the area with regard to invasive plants. Are any species invading? How well established are they? In what kinds of habitats do they occur? Are they widespread or limited to only certain types of habitats? Did they notice any differences in the types or diversity of other plant species where the invasive plants do and don't occur? What kind of management strategy would they suggest for this site? Is there other information they think should be collected?

10. Based on this discussion, have students write a summary of their findings in a report form.

11. Present or send your information to those responsible for managing the area.

Extensions

Have students complete ***Lesson 46: Invasive Plant Management: Plan to Action*** in this guide using the area you surveyed.

Name ____

Invasive Plant Survey Data Form

Study Site: ____

Survey Route Number: _______________ Date _________________

Surveyed by: ____

Type of habitat surveyed (e.g., wetland, forest, riparian, grassland, roadside, etc.) and brief description:

Fill out a row of the table below for each patch of invasive plants you encounter.

Plant Species	**Estimated size of patch (check one):**				
	< 1 m^2	1–5 m^2	5–50 m^2	50–100 m^2	> 100 m^2

Mark the locations of the invasive plants on your map.

Name ____

Invasive Plant Survey Summary Form

Class: ______________________________ Date: ________________

Study Site: ____

Route number	**Patch number**	**Habitat**	**Plant species**	**Patch size**

LESSON 33

Sampling Invasive Plant Populations

OBJECTIVES

Students will understand why scientists use plot samples to estimate the population size or relative abundances of invasive plants. They will know how to estimate the density and percent cover of invasive species in an area, and how to analyze data they collect and interpret the results.

METHOD

Students learn about noxious weed species in their area, and devise a comparative question that can be answered by sampling plant populations. They learn how to randomly select plot locations, make inexpensive and simple quadrat frames, and collect data on the density and percent cover of plants within the plots. They analyze and interpret their results.

MATERIALS

✎ Stakes and flagging (if you want to mark the plot locations for the future)
✎ Random numbers table or phone book
✎ ½ inch PVC tubing and elbows, made into quadrat frames (see instructions in ***Procedure***)
✎ **Plot Sampling Data Forms**

BACKGROUND

Field studies of plant populations can be used to answer questions such as:

- Are certain species more abundant in some habitats than in others?
- Do human factors such as soil disturbance affect plant populations or distributions?
- Do some species have negative or positive associations with other species?
- Do management actions affect plant populations?

Scientists and land managers often do not have the time or resources to count all the plants in the entire area of interest. Instead, they collect samples of data from the area and use it to extrapolate the information to the rest of the site. In order to select a sample that is likely to accurately characterize the area, samples are usually located randomly. This prevents conscious or subconscious bias on the part of the data collector to select certain sites. There are several methods used to sample plants, and which one is used depends on a number of factors, including what you want to know and how much time you have to collect data.

Common methods of sampling include plot sampling and transect sampling. Transect sampling involves sampling plants along a line or transect, and is useful for estimating the relative abundance of species, especially as you move

Grade level: 9-12
Subject Areas: Biology
Duration: 3 class periods, travel time/independent research time
Setting: Classroom and field site
Season: Spring, Summer or Fall
Conceptual Framework Topics: Plant distributions, habitat, invasive species management, plot sampling techniques

from one area to another. Plot sampling allows you to estimate the density and percent cover of different species. This kind of sampling can be used to compare populations in different areas, habitats, or under different disturbance levels, or to monitor the effectiveness of various management regimes.

Density is measured by counting each "stem" (or individual plant) in the plot of a particular species. This works well for plants that are relatively large and easy to distinguish between individuals, and not so numerous that it would take all day to count them. For small, abundant plants or those difficult to distinguish among individuals, percent cover is estimated. You must use the same type of measurement for the same species in all plots you wish to compare. However, you can use one measure for one species in a plot and the other measure for a different species, as long as you don't want to compare those species to one another.

In this lesson your students will use plot sampling to answer a question about plant populations.

PROCEDURE

1. You will first need to determine what question you would like to explore about invasive plant populations. If you have surveyed for invasives in an area (see kNOweeds ***Lesson 32: Weed Detectives: Surveying for Invasive Plants***), your students may be able to brainstorm questions about habitats or disturbance based on their observations. Or if your class is taking measures to control weeds in an area (see kNOweeds ***Lesson 43: Invasive Plant Management: Plan to Action***), you could use these sampling techniques to monitor your effectiveness by collecting data before and after control efforts.

2. Once your class has developed a question they wish to answer and any appropriate hypotheses and predictions to go along with it, discuss with them the importance of random sampling. (For lessons on random sampling, go to **http://www.math.uakron.edu/amc/DataAnalysis_Statistics/OldDataStat/RandomSampling.pdf**). Discuss the impossibility of counting every plant in an area, and the need to sample subsets of an area.

3. Have your students learn to identify invasive species in your part of Montana. You may want to direct them to the following sites:
http://www.weedawareness.org/weed_id.html
http://mtwow.org/Weed-ID.html

4. Build your quadrat frames. Simple and inexpensive frames can be constructed from PVC tubing and sleeves (½-inch tubing is strong but still lightweight). You will need 4 sections of tubing cut into 1-meter lengths (it is easily cut with a hacksaw) and 4 right-angle elbows. (Depending on the

abundance and size of plants you are sampling, you can create smaller or larger frames if you wish). You can easily take one side of the frame off in the field to place it under large plants such as shrubs if you need to, and frames can be transported in pieces in backpacks. You can also mark increments off on the frame in permanent marker to help estimate cover or help remember which part of the plot has already been sampled.

5. Decide on the sampling method(s) you want to use (density and/or cover) for each species. Percent cover is the estimate of the percent of ground within the plot that is covered by the plant species. This can be difficult to estimate; have students practice estimating this in plots on the school grounds. Different students will come up with somewhat different estimates. Try dividing the plot into quarters with string or imaginary lines to help them get a better idea of percentages. They can divide them into even smaller divisions until they get a more consistent "feel" for what constitutes 5%, 10%, and so on. You can also consider having them estimate cover categories: 1-10%, 10-25%, etc. They may also have questions about stem counts, such as what to do if the plot frame lies right on top of a plant. Decide as a group on a consistent way to handle these issues; they probably shouldn't spend an inordinate amount of time on such details as long as they try for consistency. Stress the need to make any comparisons "fair."

6. Select the general area you want to sample and determine how many plots you will sample (try to sample at least 10). Divide students into pairs or small groups, with each group responsible for one or more plots. When you are ready to set up your plots, have students locate plots using random numbers from a random number table or phone book. Start at one "corner" of the study area and have students walk the random number of steps in one direction along the edge of the area. Choose another number and walk into the area that many steps. This is the corner of the first plot. You may want to mark the corners of plots with stakes and/or flagging, depending on where it is, if you plan to re-sample the area, and if you have permission to do so. Repeat the plot selection process for the rest of the plots, being careful not to step on plants in the plot.

7. Have each group put the quadrat frame down at the plot location and begin sampling, filling out the Plot Sampling Data Form.

8. Emphasize to students the importance of cleaning shoes and clothing of any seeds or other plant parts after completing their sampling so as not to spread weeds.

9. After all data are collected, have students share their information and calculate the average density or percent cover for each species. They can use these results to answer their question about invasive species.

Extensions

Have students come up with additional questions they can address using these methods.

Name ____

Plot Sampling Data Form

Study Area: ____

Plot I.D. Number: ________________ Date: __________________

Sampled by: ____

Type of habitat sampled (e.g., wetland, forest, riparian, grassland, roadside, etc.) and brief description:

Type of plot (e.g., disturbed or undisturbed, wet or dry, etc., depending on what you are comparing):

Fill out a row of the table below for each species of invasive plants you find.

Plant Species	**Density (# per plot)**	**OR**	**Percent Cover**

LESSON 34

Weeds are an Earthmoving Problem

Grade level: 3-5
Subject Areas: Earth science, life science, plant biology
Duration:
Day 1: approx. 60 minutes
Day 2: approx. 30 minutes
Setting: Indoors/Outdoors
Season: Fall or Spring
Conceptual Framework Topics:
Plant ecology, impacts of invasive species on ecosystems, weed management, soil disturbance and site recovery

OBJECTIVES

Students will be able to identify signs of erosion and explain the causes of erosion, how the natural diversity of plants in the landscape can help prevent erosion and how weed invasion can lead to an increase in soil erosion.

METHOD

Students will observe and record signs of erosion in the schoolyard, demonstrate erosion using a soil tray, and discuss how invasive plants can increase erosion.

MATERIALS

- ✎ Potted plant
- ✎ Soil
- ✎ Water
- ✎ Small rocks
- ✎ Aluminum pans
- ✎ Container for pouring water
- ✎ Buckets for waste water
- ✎ Newspapers
- ✎ Netted material, such as cheesecloth or old stockings
- ✎ Pictures or specimens of local native grasses, forbs, shrubs and trees (including roots) and locally found noxious weeds (see the ***Resources*** section of this guide)

BACKGROUND

When weeds invade an area many aspects of the environment are affected, including the soil. Erosion is a gravity driven process that moves soil and other material and deposits them elsewhere. It usually occurs due to transport by wind, water, or ice; by down-slope creep of soil and other material under the force of gravity; or by living organisms, such as burrowing animals. A 2006 study from Cornell University reports that the economic impact of soil erosion in the United States costs the nation about $37.6 billion each year in productivity losses. The soil that is washed away ends up in rivers, streams and lakes, making waterways more prone to flooding and to contamination from soil's fertilizers and pesticides. Soil erosion also reduces the ability of soil to store water and support plant growth, thereby reducing its ability to support biodiversity. Erosion promotes critical losses of water, nutrients, soil organic matter and soil biota, harming forests, rangeland and natural ecosystems.

Plant diversity protects soil from erosion. Many of Montana's noxious weeds such as Russian knapweed, leafy spurge, and spotted knapweed reduce plant diversity of our native range lands, which can lead to an increase in soil exposure and subsequent erosion. Diverse native plant populations provide a variety of root systems and soil surface cover which hold soil in place and retain soil nutrients. When an invasive plant, such as spotted knapweed, invades an area its *allelopathic effects* (inhibition of growth in one species of plants by chemicals produced by another species) and ability to outcompete native plants for resources can decimate existing plant populations and kill the soil-stabilizing root systems. As a result the soil becomes more susceptible to erosion. Creek banks and steep slopes with moving surface water are particularly at risk of rapid erosion when weeds replace the native flora.

When the weeds are managed and restoration begins it can take a long period of time for the native vegetation to reestablish. To minimize soil loss during this period, mulching, grading to reduce slope, and temporary cover crops are a few of the management strategies that can be considered in order to help prevent erosion until the native plants are well-established.

In this lesson we will explore how invasive plant infestations can lead to increased soil erosion.

PROCEDURE

Day 1: Class demonstration (20 minutes)

1. Take a potted plant out of the pot, with soil intact. Discuss how the roots of the plant help to hold the soil in place. Ask what would happen if the plant was not in a pot, but in the ground where water often runs over the surface of the ground where it is planted. Introduce the term erosion and discuss how wind, water, and ice can contribute to erosion. Ask students if and where they have ever seen the effects of erosion.

2. Explain that the class is going to go out to the schoolyard to examine the effects of erosion. Ask students to remember how plants hold soil in place and to pay special attention to the placement of trees and shrubs on the school grounds. Students will be asked to take a pencil and journal or notebook to write and draw pictures about what they observe.

Outside activity (25 minutes):

1. As a class, point out some of the more noticeable signs of erosion on the school grounds. Some good examples may be found near drains, drain pipes, and at the edges of the blacktop.

2. Pair students and ask them to examine the rest of the area (let students know what the boundaries are for exploring) to look for other signs of erosion. Ask students to describe the examples of erosion they find and draw a labeled rough sketch in their journals or notebooks, including plants growing in the eroded areas.

Closing discussion (15 minutes):
After students are back in the room, ask them to share what they have recorded. Ask if anyone noticed the placement of trees and shrubs. Were the trees and shrubs were placed in particular areas to help stop the effects of erosion? Did they notice any differences in erosion where there was more or less vegetation? What kinds of areas had the most erosion? Do they have any ideas why they might have seen the patterns they did?

Day 2: Classroom review (10 minutes)

1. Review the term *erosion* and how plants help prevent erosion.

2. Discuss erosion found on the school grounds, and if they think water was a factor.

Follow-Up Activity (20 minutes):
1. Divide the class into pairs of students. Provide each pair of students with a disposable aluminum baking tray, enough soil to fill the tray about halfway full, water, small container, newspapers, some net-like material and some small rocks. Cover each working area with newspapers.

2. Instruct students to fill their tray halfway with soil. Firmly position the rocks into the soil. For each tray, cover about a quarter of the surface of the soil with the netted material, holding the edges down with rocks and tucks into the soil. Add a thin layer of soil over the top of the netting. Pat firmly down on the soil surface of the entire tray.

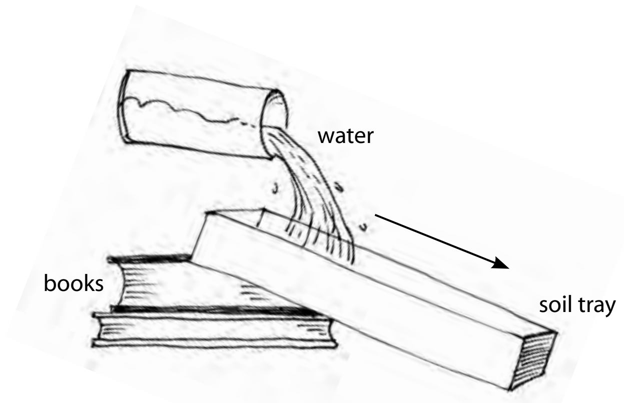
3. Place the narrow side of the tray filled with soil and rocks on one or two books, so as to place the tray on a slant.

4. Next have one of each pair of the students pour little drops of water, starting at the highest part of the tray, so the water can run down the soil.

5. Ask students to notice if any changes are taking place in their trays. See if the soil or rocks are moving out of position.

6. Direct the other student to pour larger amounts of water at the highest part of the tray, pouring off the water that collects each time the lower end of the tray becomes full of water into a waste water bucket for later disposal outdoors (do

not allow to overflow). Repeat several times to observe what happens to the material in the tray. Ask the students to describe what changes are taking place in the tray. Are they seeing signs of erosion? Have them check the net-covered area of the soil and see whether or not the soil stayed in place underneath it. How is this similar to a plant's root system holding soil in place on sloping ground?



7. Show students examples of native plant root systems (photos, drawings, pressed specimens, live plants or models of plants) including a locally found native grass, forb (small flowering plant), shrub and tree. Indicate that there are a variety of root system sizes and shapes, and this relates to their function. Ask students how a variety of kinds of roots in the landscape helps hold the soil in place (like a puzzle, the pieces fitting together to form a protective mat).

8. Ask students what would happen if a local natural area was invaded by a noxious weed, such as leafy spurge or spotted knapweed (or select a local noxious weed to your area as the example), eventually replacing the native plants. What would happen to the diversity of the root systems? Would you expect to find an increase in the erosion of soil? If so, why?

Extensions

Have students design and conduct a comparative study in the soil tray using different slopes to see how erosion increases or decreases in relation to the angle of slope. Discuss how the results relate to local sites where erosion has occurred.

Visit a local site that is being restored to native plants and help pull weeds, mulch, plant natives or conduct other restoration activities that prevent erosion and restore the natural ecosystem. See ***Lesson 41: Pulling Together*** and ***Lesson 44: The Cycle of Restoration*** found in this guide for more ideas.

LESSON 35

Wildlife Weed Woes

Grade level: 5-8
Subject Areas: Science, math, physical education
Duration: Two 45-minute sessions, extra time for group presentations may be needed
Setting: Outdoors or in gym, then classroom
Season: Any
Conceptual Framework Topics: Invasive species, weed management, ecological impacts of invasive plants

OBJECTIVES

Students will be able to describe the food needs of a species of Montana's wildlife and identify the impacts that noxious weeds can have on its population.

METHOD

Students role-play foraging elk and gather cards representing different types of food. They then calculate their food intake and how the presence of spotted knapweed might affect food availability for elk.

MATERIALS

- ✎ Colored construction paper cut to 2" x 2" (30 each of yellow, green, and brown; 90 purple)
- ✎ **Individual Recording Sheet** (1 per student)
- ✎ **Group Activity Directions** sheet (1 per group of 5 students)
- ✎ Envelopes (1 per student)
- ✎ Paper
- ✎ Pencils
- ✎ Calculators (optional – 1 per student)
- ✎ Weed identification guides

BACKGROUND

Noxious weeds contribute to the loss of wildlife habitat. Dense infestations of noxious weeds reduce wildlife forage, reduce cover for wildlife to escape predators or hunt for their food, decrease cover for protection from the elements, and change water flow and availability to wildlife. Areas dominated by leafy spurge have been found to receive less use by deer (3 times less use) and bison (4 times less use) compared with similar uninfested areas. Elk use has been found to decrease by 98% on spotted knapweed-dominated range compared to native bunchgrass-dominated sites. Noxious weeds alter the functioning of riparian (wetland) areas. These weeds often lower water tables and, in some areas, have eliminated surface water and native vegetation needed by wildlife.

To illustrate the impact of weeds on wildlife, we can look at one of Montana's game species, elk. The average adult elk weighs more than 500 pounds (225 kg), and eats about 15 pounds (7 kg) of food per day in the spring, summer, and fall, and about 10 pounds (4.5 kg) in the winter. These amounts and type of plants eaten can vary across the state. In spring and summer elk eat a mixture of grasses and forbs (small flowering plants). In the fall they primarily eat grasses and browse (the woody parts of plants). In winter they eat more browse because other sources of food are not as available. Because browse takes more energy to chew and digest yet provides fewer calories than other food sources, elk typically need to rely on their body fat to help them survive through the winter season.

This lesson uses figures that represent the yearly average of a typical adult elk's diet in the northern Rocky Mountains. Invasive weeds degrade elk habitat. Land managers often use tools such as seeding, fertilization, water projects, noxious weed treatments, prescribed burning and protective fencing to restore elk habitat. In this lesson students will learn about how invasive plants can impact elk by replacing their natural food sources with plants that less palatable and nutritious.

PROCEDURE

Before doing the activity, cut the construction paper into 2" x 2" cards. For a class of approximately 25 students, make cards of each of the four colors as listed below. Mark the cards as follows (the number after each letter is the number of pounds of that kind of food the card represents):

Yellow (Grasses)—Mark 8 cards G-2000 and 22 cards G-1000

Green (Forbs)—Mark 8 cards F-1250 and 22 cards F-625

Brown (Browse)—Mark 8 cards B-1750 and 22 cards B-875

Purple (spotted knapweed)—Mark 33 cards G-2000, 33 cards F-1250, and 24 cards B-875

1. Begin the activities outdoors or in a gym. Hand out one envelope to each student and have them write their name on it; this will represent their "stomach."

2. Mix and broadly scatter the cards in the playing field. Designate a starting line.

3. Have students line up on the starting line, leaving their envelopes between their feet on the ground. Explain they are elk looking for food and that their envelopes represent their stomach. *Don't tell them what the colors, letters, and numbers represent.* Tell them the cards represent various kinds of elk food. Elk eat different kinds of food at different times of the year, and students will gather different colored squares to represent a variety of food.

4. Explain to students that they must WALK into the area because elk don't run down their food, they graze. When students find a colored square, they should pick it up and return it to their envelope (their "stomach") before picking up another square.

5. Have the students begin gathering food. When all the colored squares have been picked up, the food gathering is over. Return to the classroom with the envelopes of food.

6. Divide the class into groups of 5 students, and hand out the **Individual Recording Sheets** (1 per student) and the **Group Activity Directions** (1 per group). Tell students that they should each take the time to fill out their Individual Recording Sheet (using calculators if needed), then follow the instructions on the Group Activity Directions sheet. Each group will then report to the whole class using a poster they create to illustrate their findings. Each student will need a piece of paper and a pencil.

7. After the students have finished their investigation of elk habitat and their posters are ready, allow each group time to report and present their findings to the rest of the class.

8. Summarize their findings and discuss different reasons elk might or might not have survived. Point out when these are examples of limiting factors. *Limiting Factor: something that limits the ability of the particular species to survive in that habitat.*

9. What are some other limiting factors that may affect the survival of elk? Would these factors be similar for other wildlife in an ecosystem?

10. How can knapweed decrease the availability of resources for wildlife? Move into discussion on other noxious weeds found in Montana and their similar effect on wildlife habitat.

11. Conclusion: What can you do to help take care of wildlife habitat?

Extensions

This activity can be adapted for other Montana wildlife species by asking students to research another Montana wildlife species depends on plants for food. Identify its natural food sources and average amounts of food needed each year, as well as how invasive plants threaten to replace its natural food sources. Use the student research results to adapt the game in the lesson to illustrate the impacts of weeds on a range of Montana wildlife species.

Name ____

Individual Recording Sheet

Elk need 5,000 pounds of food every year to survive. A balanced diet for elk includes:
Grasses ...... 2,000 pounds = 40% of an elk's diet
Forbs .... 1,250 pounds = 25% of an elk's diet
Browse....... 1,750 pounds = 35% of an elk's diet
TOTAL.......5,000 pounds = 100%

Elk use has been found to decrease by 98% on spotted knapweed-dominated range compared to native bunchgrass-dominated sites.

Your cards are different colors because they all mean something different:

Yellow Cards are grasses, and the number on them shows the pounds eaten

Green Cards are forbs, and the number on them shows the pounds eaten (forbs are flowering plants)

Brown Cards are browse, and the number on them shows the pounds eaten (browse are the woody parts of plants)

Purple Cards represent spotted knapweed, a noxious weed (this is not considered a food source for elk)

Using the cards you collected in the game, fill in the following information:

1. Add up the total pounds of food you gathered (the total of the numbers written on of all of the different colored cards you gathered).

   Record the amount here: ________________pounds. Based on total pounds, do you expect to survive? (circle one) Yes No

2. What is the total for your purple cards only? ___________________pounds

3. Subtract the amount of purple card pounds from your overall total: ________________pounds, since knapweed is not a palatable food source for elk but its presence reduces the amount of elk forage available. If you survived in #1, did you still survive once you subtracted out the spotted knapweed from #3? (circle one) Yes No

4. Now separate your cards into piles according to letter code (G, F, and B)
   Don't leave purple in its own pile, but match the letters on the purple cards up with letters on the other cards. Total up the amount of pounds for each code letter.

   Write your totals : G (Grasses) ________________________ F (Forbs) ____________________________
   B (Browse) ________________________

5. Elk need a balanced diet, just like humans do, in order to survive. By checking the chart provided to your group, did your elk have a balanced diet during the year? (circle one) Yes No

6. If you took out all of the purple cards that represent spotted knapweed, would your elk still have a balanced diet? (circle one) Yes No

Group Members: ______________________________

Group Activity Directions

Background Information:
You have just picked up a variety of cards and put them in your envelope. Each card represents a different type of forage available to elk during the year. You can check the information sheet attached to find out more about the types of food an elk needs, and how much of each food they need. Every year, the average elk needs 5,000 pounds of food in order to survive. During this activity, your group will be figuring out if each elk consumed enough food. You will determine whether or not spotted knapweed had an effect on your elk's diet. Spotted knapweed, a noxious weed, is not very palatable to elk, and does not provide elk with as much nutrition as native grasses, forbs (flowering plants), and browse (woody plants) do.

Directions:

Step 1: You will need to designate a job for each group member. Write the name of the member next to the job below.

Group Leader (organizes group and reads directions) ______________________________

Recorder (writes down your findings) ______________________________

Researcher (looks up information and reports to group) ______________________________

Analyzer (helps everyone make sense of the data) ______________________________

Designer (helps design the poster that is your final product) ______________________________

Step 2: The *Group Leader* reads the instructions and keeps the group on task. First, each group member gets their own **Individual Recording Sheet**. Complete this page first. Next, each member shares their information and the *Recorder* for the group will be in charge of recording all of the information and compiling it.

Which members of your group survived the year? The *Analyzer* can be an important person here. Everyone should be doing their own math problems, but the analyzer can help when needed.

Step 3: After you have finished the activity, you will be giving a very short report to the rest of the class to share your findings. With the help of your group's *Designer*, you can use any materials you would like to design and create a poster that shows what you found out as a group. You can include charts, graphs, drawings, or cutouts from brochures, and the *Researcher* can provide extra help in finding information and materials. (Please don't cut up books or pocket guides!) Your poster needs to show the rest of the class what you found out.

Now that you have completed this group activity and your poster is ready, decide how you are going to report to the rest of the class. Is only one person going to talk? Are you going to take turns? Get ready to share your findings.

TAKING CONTROL AND LENDING A HAND:

Learning How Invasive Plants are Managed and Turning Knowledge into Action

Common Tansy
Tanacetum vulgare

kNOweeds

LESSON 36

Stop that Weed!

Grade level: 2-6
Subject Areas: Life science, dramatic play
Duration: 45 minutes
Setting: Indoors or Outdoors
Season: Any
Conceptual Framework Topic: Integrated weed management, weed control, noxious weeds

OBJECTIVES

Students will be able to discuss ways that invasive plants (including noxious weeds) can be controlled and describe how unwanted invasive plants compete with native plants.

METHOD

Students learn about methods of weed control while participating in games in which players represent roles in weed control scenarios.

MATERIALS

✎ Name tags marked with the following (1 title per tag):
  WEED and NATIVE PLANT (9 tags of each)
  HERBICIDE, INSECT and GRAZER (3 tags of each)
✎ Blindfolds (enough for all the WEEDS and NATIVE PLANTS combined)
✎ Whistle

BACKGROUND

When invasive plants such as those on the Montana's Noxious Weed List spread into natural areas, they can crowd out native plants, changing the structure and function of the entire ecosystem. Fighting the spread of invasive weeds often involves the use of multiple weed control tactics as part of an integrated weed management plan. Herbicides can be effective but expensive and may have harmful effects on other species. Mechanical removal of weeds by pulling, tilling, mowing, burning and grazing can help reduce their spread but usually will not eradicate the plants completely. Biological control agents, such as insects that feed on the plants, can be effective but may take time to establish and may have unintended consequences on other species. When weeds have been reduced, the chances of reinvasion can be minimized by seeding with desirable native plants that are capable of competing with the invasive species.

PROCEDURE

1. Discuss with students the possible effects of a weed invasion. Relate the topic to their experiences of what they have observed on hikes or in their own backyard or garden. Elicit students' ideas about how weeds become numerous. Ask, "What do you think happens to the other plants when weeds take over?"

2. Introduce the idea of competition (when living things need the same resources, such as sunlight, nutrients and water). Remind students of their experiences playing "musical chairs" to reinforce the concept of having too many individuals who want the same space.

3. Tell students that since we have come up with some reasons that we don't want weeds to invade and take over, it's time to think about what we can do to fight them.

Play one or both of the following games:

GAME 1

1. Start with approximately three times as many WEED and NATIVE PLANT name tags as weed control tags (HERBICIDE, INSECT, and GRAZER). Explain that INSECT tags represent insects that feed on the weeds but do not eat the native plants.
2. Lay the name tags face down and allow each student to pick one.
3. Define the boundaries of the game and help students who will be blindfolded by letting them know if they leave the game boundary you will blow the whistle to indicate a quick time out for going "out of bounds," during which you will help them return to the center of the game area, then restart the game. If one of the weed controls (not blindfolded) goes out of bounds, they will be eliminated from the current round of the game and asked to wait in the sidelines.
4. Blindfold the students with the WEED tags. These will stand near one another in the center of the game area. The other students will be dispersed within a small distance around the WEEDS. The blindfolded students try to touch, grab, or hold the other students in the group. The other students can clap and make noise to confuse the blindfolded WEEDS as well as to get attention.
5. If a WEED touches a student with a NATIVE PLANT tag, the native plant becomes a WEED and is also blindfolded. If a WEED touches any control student, the WEED is out of the game.
6. The game continues until all WEEDS are out of the game.
7. Change the number of students in each group to see how the outcome is affected.

GAME 2

1. Start with approximately three times as many WEED and NATIVE PLANT name tags as weed control HERBICIDE, INSECT, and GRAZER) tags. Explain that INSECT tags represent insects that feed on the weeds but do not eat the native plants.
2. Lay the name tags face down and allow each student to pick one.
3. The students form a circle. Choose one student with a WEED tag to come out of the circle and run around it.
4. At a random time, blow the whistle. The WEED should immediately join the circle by touching, then replacing, another student.
5. Check the name tag of the person that was replaced by the WEED.
6. If the replaced person is a NATIVE PLANT, the WEED gets into the circle and the game continues with the native plant running around the circle until the whistle is blown.
7. If the replaced person is a control, the WEED is not allowed to enter the circle and should stand out. He or she is considered to be "weeded out." The teacher picks out another WEED or NATIVE PLANT to run around the circle.
8. The game ends when there are no more WEEDS in the circle.
9. Try changing the number of weed control name tags to see how the outcome of the game is changed.

Wrap-up: Gather the students and discuss the activity with them. Students may also write about how weeds affect other plants and how they can be controlled.

Extensions
Students conduct research on the best ways to control one of the plants from ***Montana's Noxious Weed List*** and present a report to the class.

LESSON 37

The Great Race for Survival

Grade level: 3-8
Subject Areas: Biology, ecology
Duration: 30 minutes
Setting: Outdoors
Season: Fall or Spring
Conceptual Framework Topics: Plant ecology, invasive species ecology, and weed management

OBJECTIVES

Students will understand that invasive plants compete with native plants for resources, and can often spread aggressively and negatively impact native plant populations.

METHOD

Students participate in a game in which each person represents a noxious weed or a native plant. Environmental factors are introduced, illustrating how invasive plants can outcompete native plants in a new environment.

MATERIALS

- ✎ 10 yellow cards with the names/pictures of noxious weeds
- ✎ 10 green cards with the names/pictures of native plants.
  (All plants listed in ***Procedure*** except for Cheatgrass can be found in *Coloring Pages* in the back of this guide)
- ✎ Tape measure

BACKGROUND

Plant competition for limited resources can be likened to a race for survival. Invasive plants, in the absence of the limiting factors they evolved with in their place of origin (i.e. disease, insect predation and interspecific competition), can increase in population size rapidly and negatively impact native plant populations. Invasive plants are listed as *Noxious Weeds* in Montana if when established they become destructive and difficult to control by ordinary means of farm practices. It is the legal responsibility of the landowner to control these invasive plants per the Montana County Noxious Weed Control Act.

In this lesson, noxious weeds and native plants compete under a range of conditions and herbicide treatments. The results illustrate to students that invasive species can be aggressive competitors against our state's native plant populations. Weed management is important for protecting Montana's natural heritage and reducing the impact of invasive plant species.

PROCEDURE

Students are going to become plants in a "race for survival." Give each student a plant species card. There are 20 cards. You may have to double-up students assigned to one card or give more than one card to some students, depending on the number of students in the class.

Line up students at a starting line, indicating they will move towards a designated "finish line." Read the following out loud:

Extensions

Students identify local native plants and invasive plants of local concern and gather detailed information on their growth, reproduction, ideal growing conditions, method(s) of spread, and for the weeds, suggested approaches to their control and how those methods will affect other plants in close proximity. The class will then use what they have learned to create a more extensive version of this game, which will include weed control treatments.

1. It is early spring. Rain, snowmelt, warm temperatures, and long days result in rapid plant growth. Plants send up new shoots from the soil, and seeds have started to grow. **Everyone step forward five steps.**

2. The soil along this road bed contains many more seeds from some types of plants than others. **Cheatgrass and spotted knapweed step forward two steps. houndstongue step forward eight steps.**

3. The growing season continues to be favorable. **All plants step forward ten steps.** Cheatgrass completes its life cycle the fastest, and it produces seeds long before the other species. **Cheatgrass step forward five steps.**

4. A few species are capable of producing chemicals that they release into the soil. These chemicals inhibit the growth of nearby plants. Spotted knapweed plants raise your hand. **Any plant within arms length of this plant step backward three steps.**

5. As the growing season continues, drought hits this area and plant growth slows. Deep-rooted plants do best. **Leafy spurge and Dalmatian toadflax step forward two steps.**

6. Summer storms and slightly cooler temperatures improve growing conditions for all plants. **All plants step forward six steps.**

7. Leafy spurge, raise your hand. This plant pops its seeds up to 15 feet from the base of the plant, like popcorn. This allows this plant to spread its seeds downstream for hundreds of miles! **All plants within 15 feet of leafy spurge step backward three steps.**

8. Plants continue to grow, but shorter days slow their growth. **All plants step forward four steps.**

9. Much energy is now devoted to food storage and seed production. **All plants step forward two steps.**

10. Some plants release seeds. Those that are able to produce a lot of seeds help ensure their success. Dalmatian toadflax produces 500,000 seeds per plant. **Dalmatian toadflax step forward five steps.**

11. **End the game and see which plant(s) have won the race!**

Discuss the following with the students:
Who won the race?
Why were some species more successful than others?
Which plants were most successful, the invasive species or native species?
What are some of the characteristics that enabled invasive species to succeed?
When weeds "win" or survive, what happens to other plants?
What are the consequences to other plants, animals and humans?
When invasive plants win or survive, who loses?

LESSON 38

Spotted Knapweed and Gall Fly Lab

OBJECTIVES

The students will be able to define the term noxious weed. They will be able to explain what a biological control agent is and how it is part of Integrated Pest Management. They will also be able to explain or draw the life cycles of spotted knapweed and a spotted knapweed gall fly.

METHOD

The students dissect a spotted knapweed seed head infected by the spotted knapweed gall fly, observing and drawing a gall and larvae. They collect data on the numbers of galls per seed head and predict the number of gall flies that will emerge from 100 seed heads. The students count the gall flies that actually emerge from 100 seed heads in a cage and compare what they predicted to what they found.

MATERIALS

- ✎ An outdoor area with spotted knapweed (*Centaurea stoebe*) infected by one or both of the spotted knapweed gall flies, that you can go to in the winter (In Montana, the gall flies occur almost everywhere knapweed occurs.)
- ✎ Clippers for harvesting plants
- ✎ Gloves
- ✎ Hand lenses and/or stereoscopes
- ✎ Hand dissection equipment: forceps (tweezers), teasing needles, scissors
- ✎ An insect cage (1 m square cages from Bioquip work well) **www.bioquip.com**
- ✎ Insect aspirators (bug suckers) (available from scientific supply companies)
- ✎ Insect pins (available from scientific supply companies)
- ✎ Textbooks with sections on insects and flowering plants (including the life cycles)
- ✎ Insect and plant field guides
- ✎ Trash bags (extra durable)
- ✎ **Spotted Knapweed and Gall Fly Lab sheet**

BACKGROUND

Spotted knapweed (*Centaurea stoebe*) is a Category 1 Noxious Weed in Montana. It is a native of Europe and Asia and was accidentally brought to North America by humans. However, the creatures (insects, bacteria, fungi, nematodes, etc.) that help keep its populations in check in Eurasia were not brought along with it to North America. Spotted knapweed, at least in part, outcompetes native North American plants in their native habitat because the native plants are constantly being fed upon by the many native creatures that

Grade level: 6-12
Subject Areas: Life science
Duration: 1 outdoor session, ongoing observation for 1-2 months, and several indoor class sessions
Setting: Outdoors/ Classroom
Season: Winter
Conceptual Framework Topics: Invasive species, weed management

Adapted with permission from author Todd Breitenfeldt.

have evolved with them over time. Spotted knapweed in Montana can become invasive unless humans intervene to control it.

To help solve this spotted knapweed problem, people have gone to Europe and searched for biological control agents that can help reduce spotted knapweed populations. These creatures are then rigorously tested to make sure that they are host specific (i.e., eat ONLY spotted knapweed). They are then brought back to North America, studied some more, and finally released into the field in hopes that they will help control this noxious weed. Integrated Pest Management (IPM) can use biological control agents along with a range of other available management strategies to help reduce the weed population.

In this lab you will be using two insects imported from Europe whose larvae form galls in the seed heads of spotted knapweed and reduce seed production of the plant. These small flies are *Urophora affinis* and *Urophora quadrifasciata* (Diptera: Tephritidae). In short, the flies lay their eggs in the seed heads of spotted knapweed in the summer and larvae soon hatch from the eggs. This causes the plant to form a callous-like swelling around the larvae called a gall (thus the name spotted knapweed seed head gall fly). The fly larvae feed on the *parenchyma* tissue inside of the galls. So their impact on the plant occurs by inducing the gall formation which causes the plants to put energy into gall production when they should put energy into seed production. The result is an energy sink that reduces seed production. These larvae stay in the seed heads all fall and winter. In late winter or early spring they pupate while still in the seed head and emerge as adults in late spring or early summer, to do it all again. Note that some of the other seed head biocontrol species do actually feed on the seeds directly.

PROCEDURE

1. Review the definition of a *noxious weed* and show students a picture or specimen of spotted knapweed, a common noxious weed in Montana.

2. Spotted knapweed seed head collecting: Identify a spotted knapweed-infested site. Get landowner permission and find out if other seed head insects have been released in the area (they may interfere with your class data if they are present and damaging the seed heads). Few landowners mind if you take weed seeds off their property! Gather tools: clippers, gloves, bags for seed heads (use strong bags so as not to leak seeds). Right before or soon after winter break, go to your spotted knapweed site and randomly collect enough seed heads that each student will have 5 and you have the 100 you need for the cage, plus 100 or so extra for practicing dissection. Transport these immediately to a secure

location so as not to risk spreading seeds. Be sure and use gloves as the plants are sharp and the plants have toxins you will not want in contact with bare skin. Transport without spreading the seeds. *Note: Do not collect them too early in the fall as the larvae need an extended period of cold before they will emerge. Also, do not wait and collect them too late in late winter as they will start to pupate and the students cannot see the larvae.*

3. Set up dissection and observation equipment. Demonstrate then have each student dissect at least one practice seed head, count the galls, and observe and draw the galls and larvae.

4. Have students go to lab stations, dissect 5 seed heads, count the galls in each, and record this. They will use these data to figure the average number of galls/ seed head.

5. Place 100 seed heads in an insect cage. Place the cage in a warm, well-lit area that does not receive direct sunlight. Lightly mist seed heads with water weekly.

6. Have the students use the class average to predict the number of gall flies they expect to emerge from the seed heads in the cage. For instance, if the class average was 4.32 galls/seed head, they should expect 432 flies to emerge from the 100 seed heads in the cage (class average # of galls/seed head x # of seed heads = expected # of flies).

7. Have the class observe the cage each day. After several weeks, flies are expected to start to emerge. The students should aspirate (remove from cage with a bug sucker) and count the flies each day. They should record the number emerged each day and keep a total number of flies emerged. Flies will emerge for about a month. Note: it will be too early to release the flies into the environment (there are plenty of flies!!) so preserve them in a freezer or in alcohol. The students can mount them for display and study. When the flies are through emerging, have the students use their data to complete their lab write up.

Name ______________________________ **Due Date** ______________

Spotted Knapweed and Gall Fly Lab

Procedure:

1. Observe the teacher demonstrate how to dissect a seed head and count the galls.
2. Practice a seed head dissection on the practice seed head. Data: Using a hand lens or a stereo microscope, draw a gall. Break a gall carefully open and draw the larvae.
3. Carefully dissect 5 seed heads and count the galls in each. Data: Record these 5 pieces of data and list them on the board.
4. Data: Record all the data for the whole class.
5. Find the average number of galls/seed head (the sum of the # of class galls divided by the total number of seed heads).
6. As a class, place 100 (or more) seed heads in an insect cage. Place the cage in a warm lighted area not in direct sunlight. Lightly mist seed heads with water weekly.
7. Predict: using the formula **(class average x #seed heads = expected # of flies)** predict the number of flies that should emerge from the seed heads in cage.
   _________ = expected # of flies (show your work).
8. Observe the cage each day. After several weeks, flies will start to emerge. Aspirate (remove from cage with a bug sucker) and count the flies each day. Data: record the number emerged each day and keep a total number of flies emerged. Flies will emerge for about a month. Note: it will be too early to release the flies into the environment (there are plenty of flies!!) so preserve them in a freezer or in alcohol.
9. After the flies seem to stop emerging, wait about two more weeks to be sure all are out.
10. Mount (or display) a gall fly as your teacher directs.

Results: Describe WHAT HAPPENED while you were completing the lab.

Questions:

1. Draw and label the life cycle of spotted knapweed *Centaurea stoebe* (a flowering plant). Include: flower, fruit, seed, seedling, stem, leaf, root, pollen, stamen, pistil, and ovule. Remember, a cycle makes a complete circle.

2. a. What is a weed? What is a noxious weed?

   b. Why is spotted knapweed considered a weed? A noxious weed?

   c. What characteristics of a plant might make it become a weed?

3. a. Draw and label the life cycle of a spotted knapweed gall fly (complete metamorphosis). Include: egg, larvae, pupa, and adult.

   b. Attach (or redraw) your drawings of a larvae and a gall.

4. a. What is Integrated Pest Management (IPM)?

   b. What is a biological weed control agent?

   c. Using information your teacher provides for you and/or additional research on your own, list and briefly describe 3 other ways besides biological control that people use to control spotted knapweed.

5. The spotted knapweed gall flies generally lower seed production of spotted knapweed by 10% to 40%. They cause the plant to use some of its stored food reserve to form galls in its seed heads. Will they be able to control this weed? Why or why not?

6. a. Did more or fewer flies emerge from the caged seed heads than expected?

   b. List 3 possible reasons why you think the number differed from your expected number.

LESSON 39

Biological...*Control?*: Tweaking the Ecological Web

Grade level: 5-8
Subject Areas: Biology, language arts
Duration: One 30 to 60-minute session
Setting: Classroom
Season: Any
Conceptual Framework Topics: Ecological interactions, food webs, biological controls

OBJECTIVES

Students will understand the potential effects of biological controls on non-target species in an ecosystem.

METHOD

Students role-play different members of a Montana grassland food web, and use information collected by researchers in Montana to determine how the introduction of a biocontrol agent affects other members of the grassland community and even changes the occurrence of a deadly human disease.

MATERIALS

✎ **Biocontrol Cards** (at end of this lesson). You will need to make copies ahead of time; see step 1 under ***Procedure*** for the correct numbers.

BACKGROUND

Invasive species present serious threats to the biological diversity and ecological integrity of ecosystems throughout the world. Biological control ("biocontrol") is the introduction of an organism (usually an insect, fungus or bacteria) that has often evolved with the target plant species and causes deleterious effects on it through herbivory or disease. Biocontrols are promising for weed control for a number of reasons. They have been effective at reducing plant numbers in some cases, they reduce the need for other control methods such as herbicides, and they are self-perpetuating. Biocontrols must undergo thorough screening for host-specificity (that is, that they will only eat or cause direct harm to the target plant species and not other plants) to reduce the chance for their negative impacts on desirable species.

However, this type of careful screening doesn't prevent the use of biocontrols that may have significant impacts on food web interactions in the ecosystem to which they are introduced. These kinds of indirect impacts may be virtually impossible to foresee before introductions, although some general predictions can be made.

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Researchers Dean Pearson and Ray Callaway began to more closely study the interactions among these species. They found that as the gall fly larvae overwinter in the knapweed seed heads, they provide an abundant food source for Montana's native deer mice at a time when food is otherwise scarce. In fact, in areas heavily infested with knapweed, gall fly larvae make up 85% of deer mice diets in the winter. This allows deer mice populations to double and even triple in knapweed/gall fly areas in some winters, compared to the populations in native grasslands.

This change in a small mammal population may, of course, have further effects on the ecological web of the grasslands in western Montana, potentially affecting the predators and competitors of deer mice, as well as the native plants and insects they prey upon. But an additional very interesting twist to this story is that deer mice are the primary reservoirs, or carriers, of the Sin Nombre Virus, also known as Hantavirus. Hantavirus causes a deadly respiratory disease (Hantavirus Pulmonary Syndrome–HPS) in humans, with a 37% fatality rate among those who contract it (perhaps much higher if left untreated). The virus becomes airborne when disturbed, and humans catch it through exposure to mouse feces, usually in a building, since the virus is destroyed by ultraviolet light.

Pearson and Callaway also collected data on the Hantavirus occurrence in the deer mice in their study. They found that not only did the much more abundant mice in the knapweed areas carry Hantavirus, but that a greater proportion of them carried it than did the mice in the grasslands (although that difference was not great enough to be statistically significant.) So the prevalence of Hantavirus in areas with a lot of knapweed (and gall flies) is more than three times that in other areas. (Montana in 2005 was ranked as second only to New Mexico in the number of cases per capita of HPS in humans).

For more detailed information on this research, go to
http://www.rmrs.nau.edu/publications/2006_Pearson_Callaway/2006_Pearson_Callaway.pdf

For more information on Hantavirus, go to
http://www.hantavirus.net/

Your students should already be familiar with the concepts of food webs before beginning this lesson.

PROCEDURE

1. *Ahead of time:* Copy and cut apart enough of the **Biocontrol Cards** so that you end up with **10 bluebunch wheatgrass** and **10 spotted knapweed** cards, **6 deer mouse cards, 10** ***Urophora*** **gall fly cards,** and **4 hantavirus (Sin Nombre virus)** cards. You might want to copy them onto stiff paper or glue them onto cardboard. You can also change the numbers of each member of the web according to the number of students you have, just keep them in roughly the same proportion.

2. To begin the lesson, if they are not familiar with the concept of biological controls, ask your students to think of different ways people might reduce or control the spread of weeds. Make a list on the board of the ideas they come up with. If they don't come up with it on their own, guide them to the idea of using natural enemies of invasive species to control or destroy them, and explain that these are called *biocontrols*. Make sure they understand the concept and ask if they can come up with some potential concerns associated with introducing one non-native species to control another.

3. Now tell your students that you are going to simulate an ecological web in the classroom, and that they are going to play the roles of different members of this web, which occurs in the grasslands of Montana. Explain that there are lots of different organisms that might be part of this web, but that you are going to concentrate on only a few members of it today. Ask them what important members of the grassland might be. When they mention grass, hand out **bluebunch wheatgrass** cards to 10 students and ask them to stand in a loose group holding their cards so everyone can see what they are. (You might want to mention that bluebunch wheatgrass is a native plant and the official State Grass of Montana.) If students come up with mice (prompt by asking them what lives in the grass), hand out **deer mouse** cards to 2 students and have them mingle with the **bluebunch wheatgrass** students. Ask if any of them know the name of a disease carried by some deer mice that can affect humans in Montana. Explain as much as you need about what Hantavirus is and how it is spread to humans. Explain that deer mice are the primary carriers, and hand out 1 **hantavirus (Sin Nombre virus)** card to a student. Have them stand next to one of the **deer mouse** card holders.

*Note: If you don't have enough students for each card, a student can hold more than one card—for example, a **deer mouse** card and a **hantavirus (Sin Nombre virus)** card. You can also change the numbers of each member of the web; just try to keep them in roughly the same proportion.

6. Tell your students that now they're going to simulate some changes in the web. Explain that spotted knapweed has invaded this grassland. Ask them what changes, if anything, they would expect to see in the web. (Have half of the students exchange their **bluebunch wheatgrass** cards for **spotted knapweed** cards, explaining that knapweed often displaces bunchgrass.)

7. Now tell your students that you are going to give them some information based on research that biologists at The University of Montana and the U.S. Forest Service conducted in the past several years in Montana. Explain that in the 1970's the gall flies were introduced to try to reduce knapweed populations, since by creating galls the flies reduce knapweed seeds in Europe, where both the flies and knapweed are native. Tell them that the flies lay their eggs in the knapweed flowers, and the larvae spend the winter in the seed head after it develops, eating plant tissue, and emerge as adults in the spring. Hand ***Urophora* Gall Fly** cards out to 5 students and have them stand next to the **spotted knapweed** students. What do they think will happen?

They will likely say the knapweed turns back to grass. Explain that while the flies do decrease seed production in knapweed, sometimes by up to 50%, it hasn't been enough to stop knapweed from spreading and becoming more abundant, since knapweed still has lots of seeds. (In some places, used in conjunction with other controls, including other biocontrols, it can help reduce the coverage of knapweed, but it is not very effective when used alone.)

Ask if they can think of any other effects the gall flies might have. Give them some time to discuss. Ask if they know what deer mice eat. Explain that deer mice are omnivorous, eating all kinds of foods such as seeds, insects, fungi, etc. They eat the gall fly larvae in the winter. Now see what they predict for their web. Explain that the researchers found that the mice were three times more abundant where there were knapweed and gall flies than in grasslands without knapweed, and ask how many mice there should be now. Hand out 4 more **deer mouse** cards.

Are there predictions for more changes? Explain that Hantavirus increases more than three times, because not only are there more mice, but since their population is denser the virus in spread among them more easily, so a greater *proportion* of the mice carry it! Hand out 3 more **hantavirus** (**Sin Nombre virus**) cards.

Questions for discussion:

1. What are the implications for using the Biocontrol gall flies to control the noxious weed knapweed in Montana?

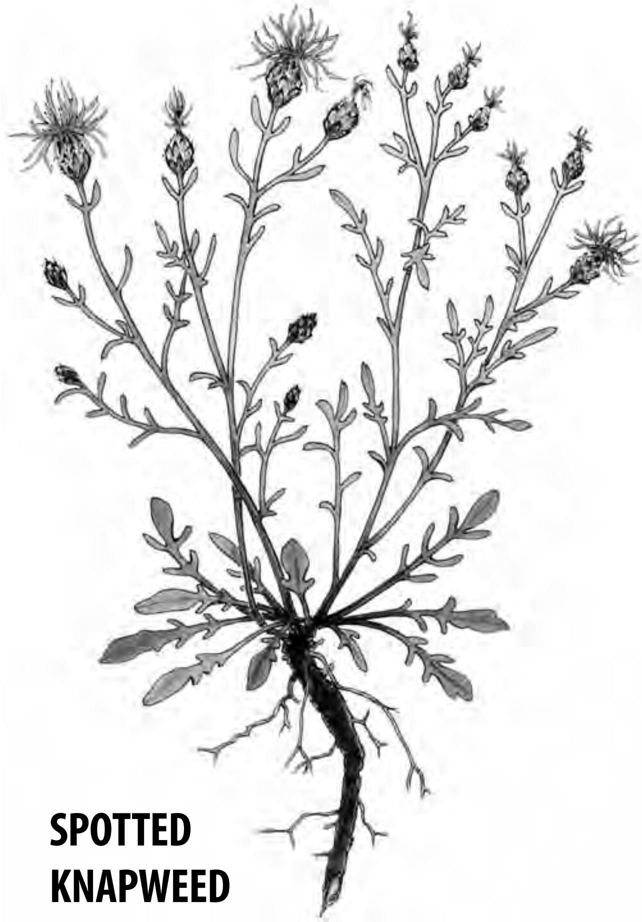
2. Could anyone have predicted that introducing gall flies to control knapweed could have an effect on a deadly human disease?

3. What other kinds of effects could these changes have? Can they imagine some other possible types of issues that might arise from introducing exotic insects or microorganisms to control invasive species?

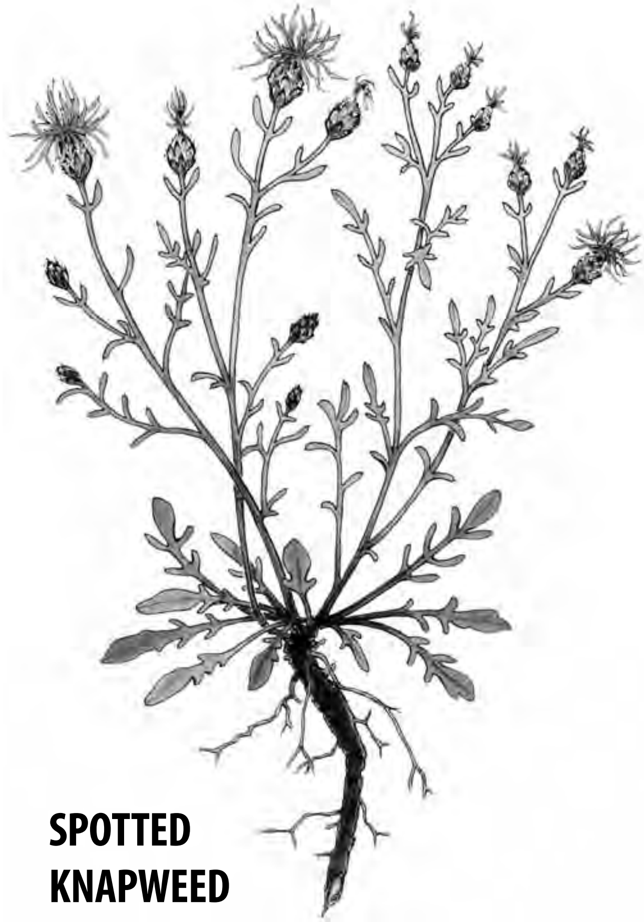
Extensions

Have the students diagram the interactions among the members of this food web.

Have students hypothesize about potential effects on the ecological web of other types of biocontrols.



SPOTTED KNAPWEED



SPOTTED KNAPWEED

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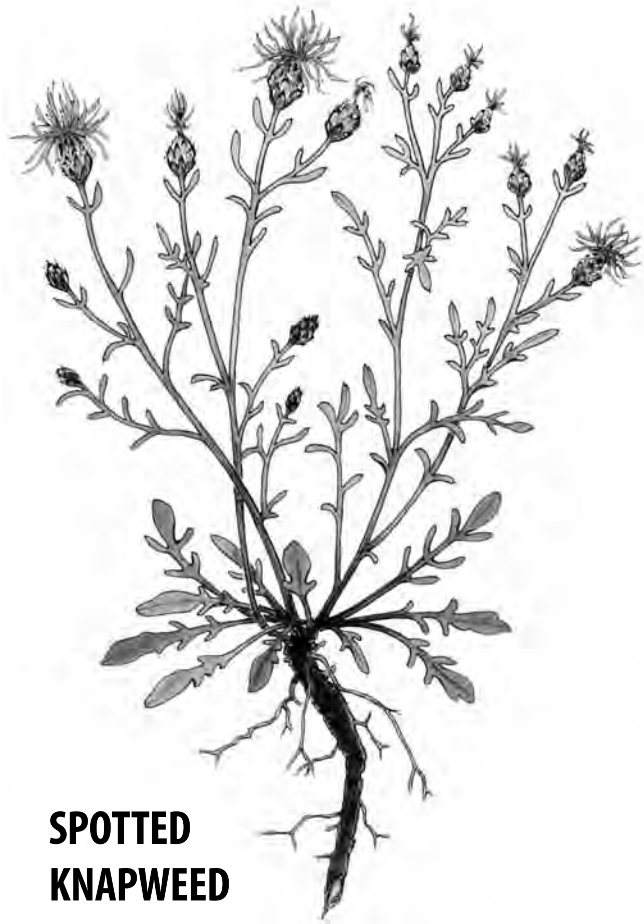

SPOTTED KNAPWEED

BLUEBUNCH WHEATGRASS

BLUEBUNCH WHEATGRASS

BLUEBUNCH WHEATGRASS

BLUEBUNCH WHEATGRASS

DEER MOUSE

DEER MOUSE

DEER MOUSE

DEER MOUSE

urophora **GALL FLY**

urophora **GALL FLY**

urophora **GALL FLY**

urophora **GALL FLY**

HANTAVIRUS (SIN NOMBRE VIRUS)

HANTAVIRUS (SIN NOMBRE VIRUS)

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HANTAVIRUS (SIN NOMBRE VIRUS)

LESSON 40

Biological … *Control?*:
Cascading Effects of Biological Control of Knapweed

OBJECTIVES
Students will understand the direct and indirect effects of biological controls on non-target species in an ecosystem.

METHOD
Students use cooperative learning to teach each other about the cascading effects resulting from an introduced biological control agent, involving the invasive plant knapweed, the biological control agent (gall flies), mice, and hantavirus.

MATERIALS
- ✎ **Student Biocontrol Pages**
- ✎ Article: *A Weed, a Fly, a Mouse and a Chain of Unintended Consequences* (included in lesson)

BACKGROUND
Invasive species present serious threats to the biological diversity and ecological integrity of ecosystems throughout the world. Biological control ("biocontrol") is the introduction of an organism (usually an insect, fungus or bacteria) that has evolved with the target plant species and causes deleterious effects on it through herbivory or disease. Biocontrols are promising for weed control for a number of reasons. They have been effective at reducing plant numbers in some cases, they reduce the need for other control methods such as herbicides, and they are self-perpetuating. Biocontrols must undergo thorough screening for host-specificity (that is, that they will only eat or cause direct harm to the target plant species and not other plants) to reduce the chance for their negative impacts on desirable species.

However, this type of careful screening doesn't prevent the use of biocontrols that may have significant impacts on food web interactions in the ecosystem to which they are introduced. These kinds of indirect impacts may be virtually impossible to foresee before introductions, although some general predictions can be made.

U.S. Forest Service and University of Montana researchers studying deer mice in western Montana realized that deer mice populations seemed to be much higher in spotted knapweed-infested areas than in native grasslands. They also found that deer mice were feeding heavily on the larvae of gall flies (*Urophora* species) that had been introduced in the 1970's to cause gall formation in seed heads and reduce seed production in knapweed. The gall flies have considerably reduced

Grade level: 9-12
Subject Areas: Biology, writing, technology
Duration: One to two class periods
Setting: Classroom
Season: Any
Conceptual Framework Topics: Invasive species ecology, weed management, biological control, herbivory, human health impacts

(Adapted from the Ecological Society of America's *Teaching Issues and Experiments in Ecology Curriculum*) the seed production in knapweed, but it has not been enough to effectively control knapweed, which continues to increase in many areas. The gall flies, however, have become as abundant as the knapweed, and are now many times more plentiful than in their native habitats in Europe.

Researchers Dean Pearson and Ray Callaway began to more closely study the interactions among these species. They found that as the gall fly larvae overwinter in the knapweed seed heads, they provide an abundant food source for Montana's native deer mice at a time when food is otherwise scarce. In fact, in areas heavily infested with knapweed, gall fly larvae make up 85% of deer mice diets in the winter! This allows deer mice populations to double and even triple in knapweed/gall fly areas in some winters, compared to the populations in native grasslands.

This change in a small mammal population may, of course, have further effects on the ecological web of the grasslands in western Montana, potentially affecting the predators and competitors of deer mice, as well as the native plants and insects they prey upon. But an additional very interesting twist to this story is that deer mice are the primary reservoirs, or carriers, of the Sin Nombre Virus, also known as hantavirus. Hantavirus causes a deadly respiratory disease (Hantavirus Pulmonary Syndrome – HPS) in humans, with a 37% fatality rate among those who contract it (perhaps much higher if left untreated). The virus becomes airborne when disturbed, and humans catch it through exposure to mouse feces, usually in a building, since the virus is destroyed by ultraviolet light.

Pearson and Callaway also collected data on the hantavirus occurrence in the deer mice in their study. They found that not only did the much more abundant mice in the knapweed areas carry hantavirus, but that a greater proportion of them carried it than did the mice in the grasslands (although that difference was not great enough to be statistically significant.) So the prevalence of hantavirus in areas with a lot of knapweed (and gall flies) is more than three times that in other areas. (Montana in 2005 was ranked as second only to New Mexico in the number of cases per capita of HPS in humans).

For more detailed information on this research, go to **http://www.rmrs.nau.edu/publications/2006_Pearson_Callaway/2006_Pearson_Callaway.pdf**

For more information on hantavirus, go to **http://www.hantavirus.net/**

(For information about use of the *Jigsaw* teaching method in this lesson see **http://tiee.ecoed.net/teach/teach_glossary.html.**)

In this lesson students will piece together the relationships between the invasive knapweed, gall flies, deer mice, hantavirus, and human health. The figures on the students' sheets come from three papers, each of which investigates separate aspects of the indirect effects of an introduced biological control agent.

Figure 1, from Pearson, McKelvey, and Ruggiero (2000), shows that the monthly variation in % stomach content (of deer mice) that consists of gall fly larvae corresponds with the yearly cycle of gall fly and deer mouse life cycles. (Students should realize after seeing this figure that deer mice are consuming gall flies as a large portion of their diet, and are only consuming gall flies when they exist as larvae within the seed heads of the knapweed. You may want to question students to make sure they understand this portion of the figure. For example, ask students why the dependent variable declines in June-Aug.)

Figure 2, from Pearson and Callaway (2006), illustrates that gall fly larvae density is higher in areas with higher knapweed density.

Figure 3, also from Pearson and Callaway (2006), illustrates that the abundance of deer mice, the *abundance* of seropositive (carrier of virus) mice, and the *proportion* of seropositive mice are all higher in populations containing higher densities of knapweed.

PROCEDURE

1. If necessary, explain to your students the basic concept of using biological controls as a method of managing invasive plants. Then tell them only the following about this specific case of biocontrol use: that gall flies were introduced in the 1970's to control knapweed; that gall flies lay their eggs in the flower heads of knapweed; that the developing larvae stress the plant and decrease seed production of the knapweed; and that this decrease in seed production has not been not enough to reduce the populations of the invasive knapweed.

2. Divide students into equally sized groups to form 3 total groups. Assign one group to Figure 1, one group to Figure 2, and one group to Figure 3. In a larger class, you can divide students into 6 groups (two groups to each figure). There are three different portions of the story represented by the three figures. Students are to interpret the data given in their figure and ensure that each member of their group thoroughly understands the information, as they will be required to explain it to someone who has not seen the figure yet. Give students sufficient amount of time to accomplish this. Make sure all the terms and concepts are understood (proportions as opposed to total number, life cycles resulting in changes of availability over time, etc).

Make sure that students read the figure legends. In particular, make sure students understand that 'seropositive' means that the mice are carriers of hantavirus. You may need to inform students that transmission rates will increase with increases in the density of the carriers. You could enforce this concept by asking students to consider the conditions under which diseases spread more rapidly (among those living in crowded cities, when people are crowded together in schools or other large buildings, etc.)

3. Then assign students to new groups, so that each member of each new group has information from a different figure. Therefore the new groups should each contain 3 members, one student having information about Figure 1, one from Figure 2, and one from Figure 3. These students are now to teach each other their "pieces" of information to "piece together the puzzle" with the goal of understanding the indirect effects of the introduced biocontrol agents.

4. As a breakdown of the figures, students should be able to conclude that (1) gall fly larvae are present in large densities in areas that contain knapweed, (2) deer mice are present in large densities in areas that contain knapweed, (3) deer mice diets primarily consist of gall fly larvae and their diets fluctuate with the life cycle of the gall fly, and (4) both the density and proportion of deer mice that carry hantavirus are higher in areas that contain knapweed. Therefore the continued presence of knapweed allows for the persistence of gall flies, which provide additional food for deer mice, carriers of hantavirus, a virus that is transmitted to humans and can be fatal.

5. After all the final groups have had a chance to share their pieces of the puzzle with one another, discuss the issue with your class as a whole. You may want to address the following:

   a. Ask if the *correlations* between knapweed and gall flies, gall flies and mice, and mice and hantavirus *prove* that the biocontrol increases hantavirus occurrence. (Although the separate pieces of the puzzle suggest that more knapweed allows more flies to flourish, which allows more mice to live in knapweed areas, which in turn causes more and a greater proportion of seropositive mice, you can explain that these were *correlations*, and *causation* has not yet been supported by manipulative experiments, which would give stronger evidence. You can discuss with students how an experiment could be designed in this system.)

   b. What do they think about the use of biocontrols to manage invasive species? For more discussion on this topic, have your students read and discuss the article *A Weed, a Fly, a Mouse and a Chain of Unintended Consequences*.

Extensions

Have students create a concept map to depict the relationships between knapweed, gall flies, deer mice, hantavirus, and human health. Ask them to consider other components of the system, such as native plants, native insects, small mammals, and predators. If your students have not worked with concept maps before, briefly describe what they are, perhaps with an example.

Have your students research biocontrol agents for invasive plants in Montana.

Student Biocontrol Page 1

Read through this page of directions and information thoroughly before examining the accompanying figure.

Individually examine **Figure 1 (graphs a and b)** and understand what the axes and data points mean. What information do the graphs provide? After everyone has completed this, discuss the figure with the other members of your group and decide what the authors wanted to convey with the data presented in the graphs. *You will need to understand the information thoroughly as you will be teaching others about it shortly!*

Share with your group any questions or difficulty you may have had with the graphs so everyone will be ready to explain them to others. Practice teaching it to each other within your group. For example, ask your fellow students: why does the dependent variable decline in June-Aug?

Figure 1 is from a paper published by University of Montana and U.S. Forest Service scientists in the scientific journal *Oecologia* in 2000. The researchers examined how much gall fly larvae make up the diets of deer mice throughout the year. The results of their study are an important piece in the ecological puzzle you will be putting together to understand the unplanned effects of an introduced biological control agent.

Gall flies (*Urophora* species) were introduced to control populations of the invasive spotted knapweed,. This species of knapweed has spread throughout the western United States and can cause many problems on rangelands and in natural areas. The biocontrol agents successfully reduced seed production of the knapweed, but not enough to effectively control populations of knapweed. However, the introduced gall flies, because knapweed still exists, continue to persist and have indirect effects on food webs and can potentially indirectly affect human health.

Now, check out your piece of the puzzle!

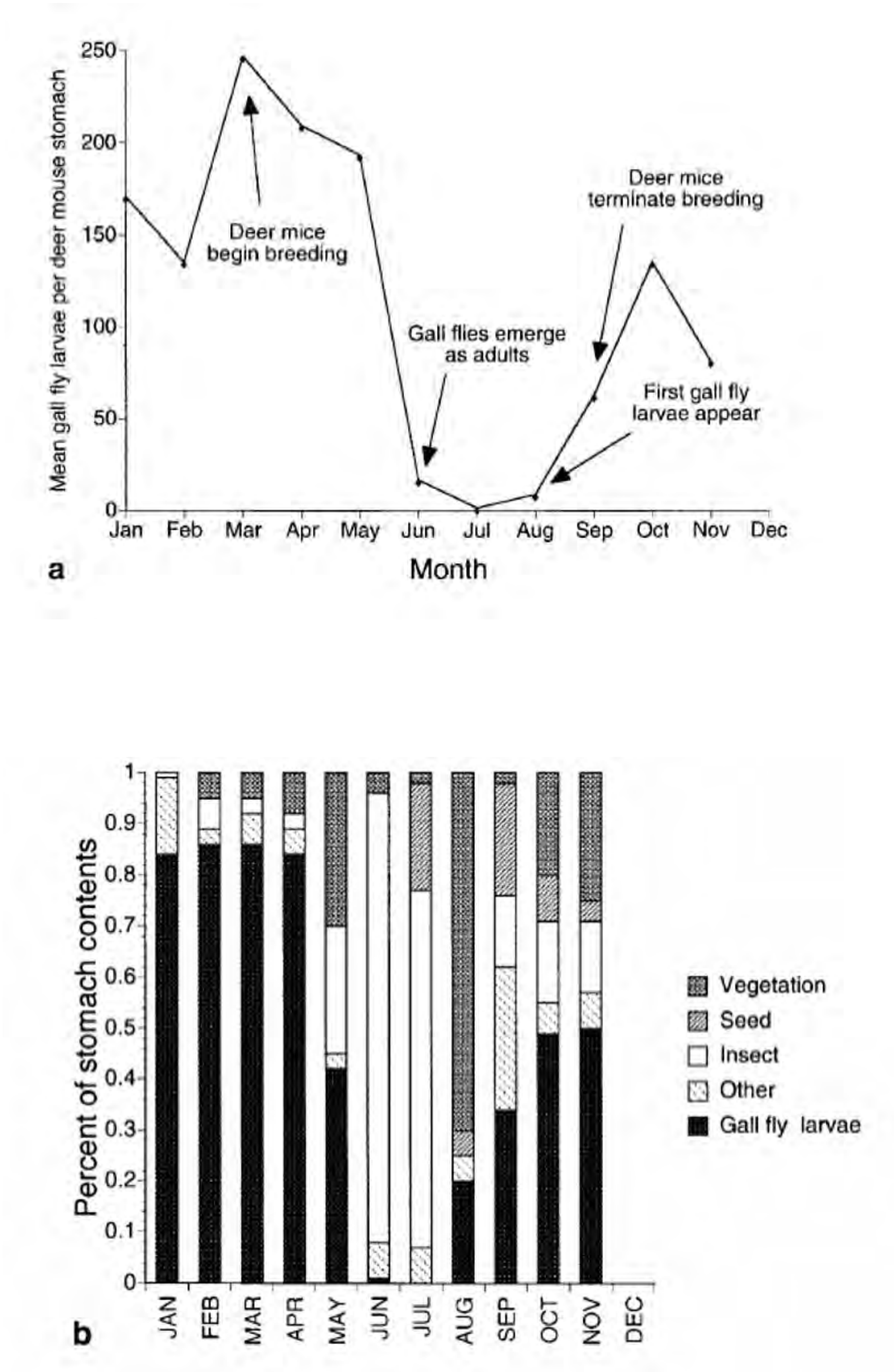

Figure 1. Stomach content analysis of deer mice from 1997-1998. Data in (a) represent mean (average) number of gall fly larvae found per deer mouse stomach each month. The arrows show different points in both the life cycle of the deer mouse and the gall fly. Data in (b) show the percent of different food items in deer mouse stomachs each month. (From Pearson, D.E., McKelvey, K.S., and L. F. Ruggiero. 2000. Non-target effects of an introduced biological control agent on deer mouse ecology. *Oecologia* 122: 121-128.)

Student Biocontrol Page 2

Read through this page of directions and information thoroughly before examining the accompanying figure.

Individually examine **Figure 2** and understand what the axes and data points mean. What information is the graph are trying to convey? After everyone has completed this, discuss the figure with the other members of your group and decide what the authors wanted to convey with the data presented in the graphs. *You will need to understand the information thoroughly as you will be teaching others about it shortly!*

Share with your group any questions or difficulty you may have had with the graphs so everyone will be ready to explain them to others. You may want to practice teaching it to each other within your group.

Figure 2 is from a paper published by University of Montana and U.S. Forest Service scientists in the scientific journal *Ecology Letters* in 2006. The researchers studied populations of knapweed (in low and high densities). One of the objectives of their study was to compare the numbers of gall flies in low densities of knapweed (where it was <2% of the vegetation) to high densities of knapweed (where it was >20% of the vegetation). They wanted to know if more knapweed means more gall flies. The results of their study are an important piece in the ecological puzzle you will be putting together to understand the unplanned effects of an introduced biological control agent.

Gall flies (*Urophora* species) were introduced to control populations of the invasive spotted knapweed, *Centaurea maculosa*. This species of knapweed has spread throughout the western United States and can cause many problems on rangelands and in natural areas. The biocontrol agents successfully reduced seed production of the knapweed, but not enough to effectively control populations of knapweed. However, the introduced gall flies, because knapweed still exists, continue to persist and have indirect effects on food webs and can potentially indirectly affect human health.

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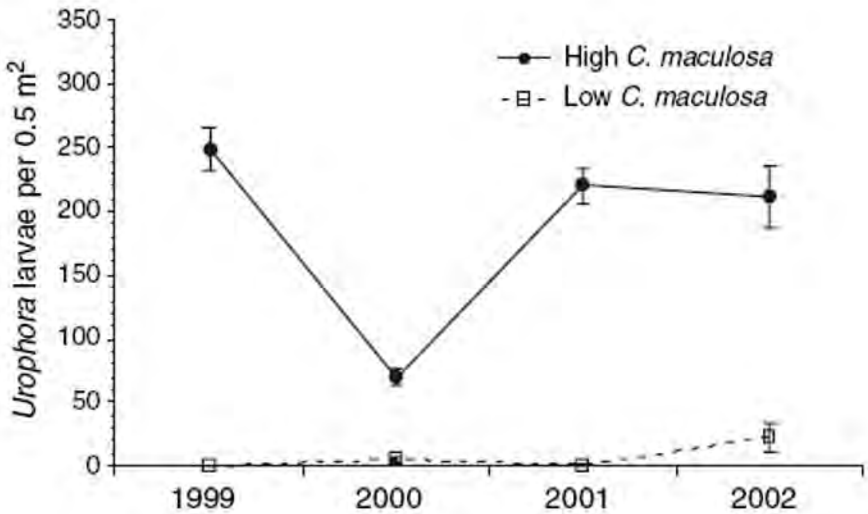

Figure 2. The mean density of gall fly larvae (+ 1 standard error) present in two populations of knapweed, one of high density (solid points) and one of low density (open points) across four years (From Pearson, D.E. and Callaway, R.M. 2006. Biological control agents elevate hantavirus by subsidizing deer mouse populations. *Ecology Letters* 9: 443-450.)

Student Biocontrol Page 3

Read through this page of directions and information thoroughly before examining the accompanying figure.

Individually examine **Figure 3** and understand what the axes and data points mean. What information is the graph are trying to convey? After everyone has completed this, discuss the figure with the other members of your group and decide what the authors wanted to convey with the data presented in the graphs. *You will need to understand the information thoroughly as you will be teaching others about it shortly!*

Share with your group any questions or difficulty you may have had with the graphs so everyone will be ready to explain them to others. You may want to practice teaching it to each other within your group.

Figure 3 is from a paper published by University of Montana and U.S. Forest Service scientists in the scientific journal *Ecology Letters* in 2006. The researchers studied populations of knapweed (in low and high densities). One of the objectives of their study was to compare the numbers of mice in low densities of knapweed (where it was <2% of the vegetation) to high densities of knapweed (where it was >20% of the vegetation). They wanted to know if more knapweed means more mice. The researchers also wanted to know if these mice were *seropositive* (which means they are carriers of Hantavirus, a potentially deadly disease in humans), how many mice were seropositive, and what proportion of the mice were seropositive in the different densities of knapweed. The results of their study are an important piece in the ecological puzzle you will be putting together to understand the unplanned effects of an introduced biological control agent.

Gall flies (*Urophora* species) were introduced to control populations of the invasive spotted knapweed, *Centaurea maculosa* This species of knapweed has spread throughout the western United States and can cause many problems on rangelands and in natural areas. The biocontrol agents successfully reduced seed production of the knapweed, but not enough to effectively control populations of knapweed. However, the introduced gall flies, because knapweed still exists, continue to persist and have indirect effects on food webs and can potentially indirectly affect human health.

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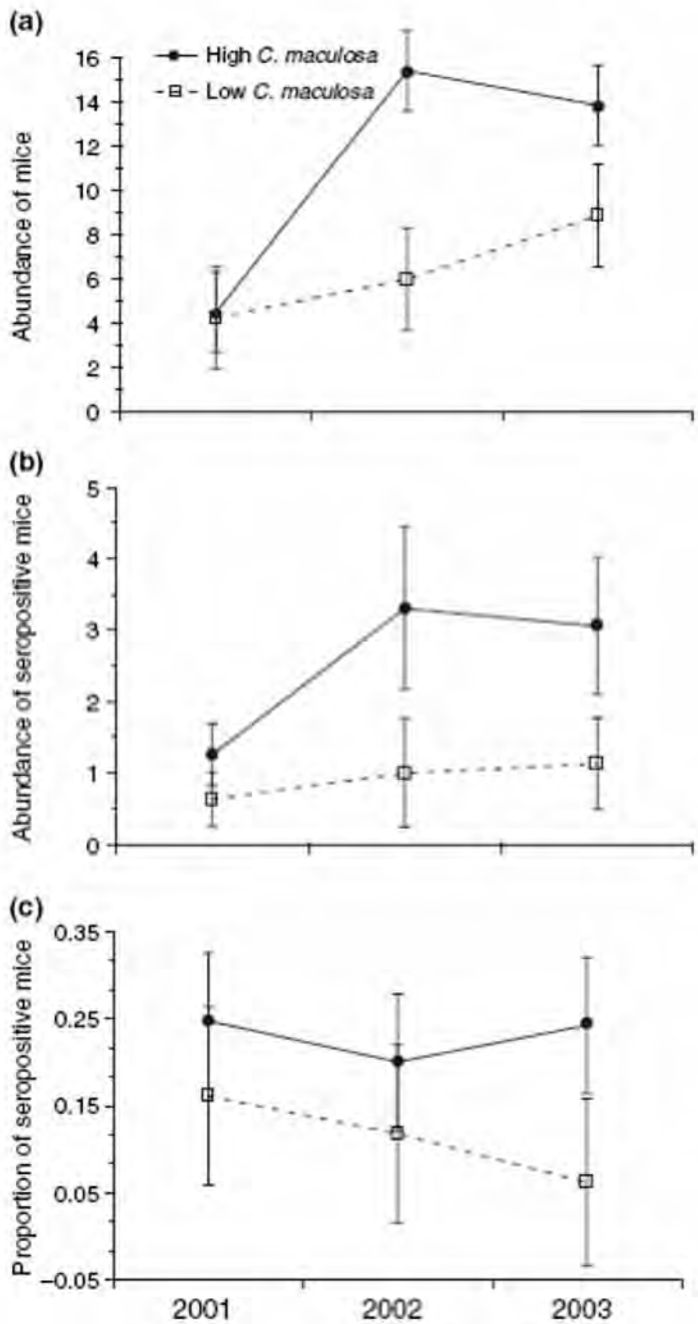


Figure 3. Data on deer mice populations in three years in areas of high knapweed density (solid circles) and low density of knapweed (open squares). (a) Abundance of deer mice. (b) Abundance of seropositive mice (mice that are carriers of hantavirus). (c) Proportion of deer mice captured that were seropositive (From Pearson, D.E. and Callaway, R.M. 2006. Biological control agents elevate hantavirus by subsidizing deer mouse populations. *Ecology Letters* 9: 443-450.)

The New York Times
nytimes.com

April 4, 2006

A Weed, a Fly, a Mouse and a Chain of Unintended Consequences

By JIM ROBBINS

MISSOULA, Mont. — First came the knapweed. Then came the gall fly. And now the mice population is exploding — the mice that carry hantavirus. In a classic case of unintended ecological consequences, an attempt to control an unwanted plant has exacerbated a human health problem.

Spotted knapweed, a European plant, is a tough, spindly scourge that has spread across hills and mountainsides across the West. In Montana alone, one of the worst-hit states, it covers more than four million acres.

In the 1970's, biologists imported a native enemy of knapweed, the gall fly. The insect lays eggs inside the seed head, and the plant then forms a gall, or tumor, around the eggs. When the larva hatches, it eats the seeds.

Dean Pearson, who works at the Rocky Mountain Research Station of the United States Forest Service, said the fly had not halted the spread of knapweed. In a report in Ecology Letters, however, Dr. Pearson reports that the introduced fly has changed the ecosystem's dynamics.

The fly larvae provide an abundant food source for deer mice in the winter, above the snow. Instead of dying out, as is often the case in cold and snowy weather, the deer mice climb the stalk of the plant above the snow to the seed head. They can eat as many as 1,200 larvae a night, at a time when there is normally no other food.

Mice numbers have tripled because of this food supply, said Dr. Pearson, and with them hantavirus, a viral infection is spread by urine and droppings. It is rare, but can cause a pneumonia-like disease that can be fatal to humans.

"It illustrates the complexity of how these things play out in the system," Dr. Pearson said. "These kinds of things are not being considered" when exotics are released, he said, and there is every reason to suspect there are other, similar examples.

Since the 1970's, the importation of an exotic plant's natural enemies from its country of origin, something known as biological control, has been considered a safe and effective alternative to pesticides. Hundreds of enemy species have been released.

Biological control has worked well in some cases to tame serious problems and reduce the need for pesticides. The classic case was the release of a beetle to control a weed called St. John's wort in the 1940's.

The beetle reduced the plant to less than 1 percent of its original range, and has kept it there. To Dr. Pearson and other critics of biological control, however, the reason the process seems safe and effective is that it has not been well studied. Once an exotic is released, in other words, it isn't followed to see what happens.

"What Dean has found is the tip of the iceberg," said Svata Louda, a professor of biology at the University of Nebraska at Lincoln, referring to Dr. Pearson's study. "We don't know what we're doing when we mess up natural systems."

A major worry is that the introduced enemy will drift off target. Dr. Louda has studied the thistle flowerhead weevil that was imported from France and Italy in the 1970's to control a weed called the musk thistle, which spread across grazing land.

In Nebraska's Sand Hills, she found that the weevil switched to Platte thistle, a native plant, and, she says, has severely reduced it. She is worried the plant could disappear. Dr. Pearson's work, however, raises a new kind of problem with biocontrol — that even if an exotic species stays on its intended target, it can disrupt ecosystems and cause environmental damage.

"This is the first time anyone has shown host specific organisms can impact nontarget species," he said. "And in this case the chain goes all the way to humans." There's no research on whether human cases of hantavirus have risen because of gall flies.

"It's good science," said Jim Story, a research entomologist at Montana State University in Bozeman who has studied and introduced biological control agents for knapweed for more than 30 years. "It helps us understand the whole system. But we've never be able to eliminate all risk. I don't think this is a huge black mark against biocontrol. Any time you bring in an exotic agent you have to assume there are going to be negative effects."

Critics, he said, should focus on the damage caused by knapweed. "We're not seeing the forest for the trees," he said. "Not too many people are focused on what knapweed is doing. We have land managers screaming at our door and wanting results." Problems with the gall fly larvae may be a moot point, he says.

An exotic root weevil that has been introduced to control knapweed shows great promise. Donald Strong, a professor of biological sciences at the University of California, Irvine, has studied the ethics of biological controls and says that, while this is a serious problem, no one could have foreseen it. On balance, he said, biocontrols are critical. "Invasive species are a huge problem," Dr. Strong said. "Biological controls are a very powerful arrow in our quiver for invasive species."

In Australia, authorities have introduced a virus, originally called rabbit hemorrhagic fever, to kill the rabbits that plague the countryside. The virus seems to be working, but the release has drawn criticism and prompted fears that the disease could spread to other animals, and is not controllable.

Problems with biological controls have emerged before in the United States. In 2001, researchers found that a parasitic fly brought from Europe to control the exotic gypsy moth had switched hosts and was attacking wild giant silk moths, a large and beautiful native moth, causing a precipitous decline in population.

Both Dr. Pearson and Dr. Louda think that exotics are too liberally used. Studies show that as many as three times as many exotics have been released as there are target species. They also say there are other things that can be done to control weeds. Rather than reduce grazing, Dr. Louda contends, the agriculture officials release beetles and the rancher can go on overgrazing.

Dr. Pearson questions a fundamental assumption of biocontrol — that pest enemies of the weeds are the factor that controls them. "The natural enemies hypothesis has dominated thinking in this field for a long time," he said. "But the reasons knapweed is not abundant in Europe may be what it competes with or climate. There could be a lot of reasons."

Dr. Pearson says the gall fly has changed the deer mouse ecosystem on a large scale. Pointing to knapweed-blanketed hills on the edge of town here, Dr. Pearson said that at one time the deer mice lived in island populations, widely separated, and kept in check by winter mortality. Now those populations are contiguous. Disruptions in ecological systems are often the cause of disease.

In the East, researchers suspect, building homes in forests has pushed out predators, which has elevated populations of deer and the white-footed mouse, which are hosts for Lyme disease. Heavy rains in the Southwest last year led to a profusion of wild flowers and food for mice, and scientists predict there could be an increase in hantavirus this year as a result.

LESSON 41
Pulling Together

OBJECTIVES
Students will be able to describe a variety of methods that can be used for weed control. Students will be able to describe the weed control approach developed by the Bradley sisters.

METHOD
Students engage in a weed pull to help native plants return to a weed-infested area. Students also illustrate or combine photographs from their weed pull session into a series of posters or a storybook that tell the story of the *Bradley Method*.

MATERIALS
- ✎ Gloves
- ✎ String and stakes or PVC piping (optional)
- ✎ Large sheets of paper and other materials for making posters or storybooks
- ✎ Field guide to native plants
- ✎ Photos or a guide book to local noxious weeds (see ***Resources*** section of this guide)

BACKGROUND
Invasive plants populate new locations when the conditions are favorable for their survival. Left unchecked, they may replace existing desirable plant species and fill open spaces, such as disturbed sites where the soil is exposed. However, humans can help stop the spread of invasive plants. There are a number of different methods for halting the spread of invasive species. These fall into the following categories: 1. Manual (pulling, digging, cutting); 2. Mechanical (mowing, plowing, fire); 3. Biological (grazing, insects, plant diseases); 4. Cultural (prevention, educating others) and 5. Chemical (herbicides). Using a combination of methods, which is known as Integrated Weed Management, is generally more effective for weed control than any single approach.

In this lesson, students will learn about one manual approach to weed control using the *Bradley Method*, which was developed by the Bradley sisters in Sydney, Australia. Using this method, the two Bradley sisters (both over fifty) cleared a 40-acre woodland reserve so successfully that the area needed only slight attention once or twice a year (mainly in vulnerable spots such as roadsides and creek banks) to be maintained weed-free. To do this they expended only a minimum amount of time: an average of 45 minutes per day between the two of them. This low-cost, low-impact approach enables restoration to occur with minimal labor or equipment.

Grade level: K-6
Subject Areas: Life science, language arts, visual arts, literature
Duration: 1 outdoor session and 1 indoor session
Setting: Outdoors (weedy area), Indoor (Classroom)
Season: Spring, Summer or Fall if visiting field site
Conceptual Framework Topics: Integrated weed management, weed control, monitoring, site recovery, and education

The *Bradley Method* can be used most successfully in natural areas where weed stands are close to or intermingled with native vegetation. This approach uses carefully planned hand weeding to tip the ecological balance in favor of the native vegetation, which is then allowed to regenerate and fill the area where the weeds have been removed. The weeding is always done outwards from the edge of the best stands of natives. The Bradley sisters recommend choosing an area you can visit easily and often, where the native vegetation meets a mixture of natives and weeds not worse than one weed to two native plants. If you choose the most heavily infested areas to clear first, the weeds will re-invade very quickly because you have provided them with ideal conditions: bare soil and full sunlight.

PROCEDURE

Gather the necessary materials including those needed for the poster or storybook activity. Find an area close to school containing noxious weeds. Select a site that primarily contains weeds that can be controlled through pulling, such as spotted knapweed. (See the ***Resources*** section of this guide to locate information on weeds and control methods that are most effective for each species.) If you or others plan to continue restoring the site using the *Bradley Method*, ideally you would select a site that has at least twice as many native plants as weed plants. *Teachers: Be sure to obtain permission from the landowner or land manager prior to conducting this activity.*

Part One: In the Classroom

Explain to students that soon we will remove weeds from a small area, but first we are going to learn about two women from Australia who used the native plants in their park to help prevent further invasion. This is the story of the Bradley sisters' method of weed removal.

The Bradley Sisters' Story

Every day the Bradley sisters would go for a walk with their dog in the park next to their home. One day they noticed that the beautiful trees and flowers that they saw since they were little girls were disappearing. Instead, they were replaced with thorny, ugly, invading weeds. The sisters decided, "These weeds have to be stopped or we will have no beautiful trees and flowers left in our park." Every day the Bradley sisters went on their walks, but this time they did something different. The sisters agreed to pull a little bit of the weeds each time they went for a walk in the park. They pulled them with their bare hands. Ouch! They only pulled the weed that grew close to beautiful native trees and flowers. They pulled them from the creeks and meadows. Slowly the beautiful native trees and flowers were able to grow and grow. Eventually they forced all the weeds away. The Bradley sisters were proud of their success. They had cleared 40 acres of weeds from the park with the help of the native plants.

They even kept a map of where they had pulled weeds and removed any weeds that tried to come into the area in order to make sure the weeds never gained ground in the area again.

Ask Students: What method of removal did the Bradley sisters use? (Manual)

Part Two: Outdoors

1. Begin by going to the selected area. Explain to students that you are going to remove invasive weeds from this area. Have students draw or take photos of what the area they treated looked like before and after treatment.

Ask students: Why would it be a good idea to remove the weeds? What are they doing to the other plants? Ask students to help identify the weeds that will be removed and verify their identification using a field guide. Point out to students that the weeds have managed to take over in this area.

2. *Ask Students:* What would be a good way to get rid of these weeds? Organize the students' answers by making a list on the paper pad. Introduce Removal Methods by categorizing their answers into the following categories:

Removal Method Categories	Examples
Manual	Pulling, Digging, Cutting
Mechanical	Mowing, Plowing, Fire
Biological	Grazing, Insects, Plant Diseases
Cultural	Prevention, Educating
Chemical	Herbicide

3. Tell the students that each of these methods may be a part of a successful plan to get rid of weeds if applied with proper planning to the right situation. Discuss with students the negative impacts of each method and ways of counteracting those negatives.

Manual: Pulling can take a long time and only covers a small area.

Mechanical: Mowing or plowing can spread seeds and destroy native plants. Fire can be dangerous to use and rarely effective at killing the live underground portions of plants.

Biological: Grazing animals (sheep, cattle) may eat native plants and disturb soil. Insects from the weed's native habitat can become pests themselves or have other unintended effects on local plants and animals.

Extensions

Have students share their posters or storybooks with other classes or in the community. Plan additional weed pull events for the selected site and engage other interested classes or groups and monitor the changes in the plant populations over time.

Have students create their own weed removal system. This can take the form of an invention or animal that could be drawn or constructed. Have students explain which removal methods are used in their invention.

Cultural: Changing our habits is not enough; we must also work to eliminate the weeds already in place.

Chemical: Some chemicals (particularly if not used properly) can harm the soil, plants, animals, and water in an ecosystem.

4. Explain to students that we are going to use the **Manual** method of removing weeds in this area, much like the Bradley sisters did in the story we heard back in the classroom. We are going to depend on everyone "pulling together" to remove these weeds. Demonstrate the correct way to pull the weeds for students, and that gloves must be worn to protect the skin from harmful substances potentially found in the weeds. Explain that if we don't pull the root of the plant it may be able to grow back quickly. Teacher Note: You may want to have students focus on one area by marking the area off with staked string or PVC pipe. This pulling activity can be made into a "Weed Olympics," with students competing to see who can make the biggest pile of weeds. Have students throw the weeds onto a tarp with a 'bull's eye' trash can set up in the middle.

5. After pulling the weeds have students help bag the weeds for proper disposal so that their seeds will not spread. Return to the classroom.

6. Ask students: Were we able to get all of the weeds in our area? (No. We cannot get all of the seeds in the ground or weeds from other areas.)

Teacher Help: Stress the importance of pulling weeds over time to slowly return the area to native plants. How can the native plants help us get rid of the weeds? (Pulling weeds can help the natives come back into the area and keep the weeds out, particularly if combined with replanting of natives.)

Why should we keep a map of where we have pulled? (We will be able to keep track of the weeds and tell others about our work to restore the native plants.)

7. Have students create a poster (or storybook) using the Bradley sisters' story from above and their own experience with the weed pull. Have students use photos or draw the important steps in the Bradley method.

After removing weeds the group may be able to watch and maintain this area to keep it free from weeds, and/or invite other classes to join in this project.

LESSON 42

Burning Questions

Grade level: 5-8
Subject Areas: Science, mathematics
Duration: 30 minutes
Setting: Indoors
Season: Any
Conceptual Framework Topics: Ecosystems, invasive species ecology, succession, weed management, controlled burning

OBJECTIVE

Students will understand that soil insulates the roots and rhizomes of plants during fire, and many plants can survive even the most intense fires. Students will understand that many invasive plants can outcompete native or other desirable plants after a fire.

METHOD

Students use a “model” to represent the soil layers surrounding plants during a burn in order to measure the rate and extent of temperature increase due to heating. One set of measurements (for one thickness of insulation) is obtained as a demonstration, then students gather additional data at an activity center.

MATERIALS

- Hair dryer
- Thermocouple or digital thermometer
- Graph paper
- Clock with seconds hand
- Rulers (cm)
- 50 pages of newspaper (a thickness of 5 pages will represent one layer of soil)
- Brown fabric approximately the size of a newspaper page
- Overhead projector and pens
- Matches

BACKGROUND

Soil insulates roots from heat, and heat rises up from the top of the burning layer of organic matter (primarily plant material) during a wildfire.

As teacher, begin this activity by demonstrating the lighting of a match, and have students observe that the flame rises upward, as does the heat it puts off as it burns. Ask students what would happen if the match were clamped upside down while it burns, would the heat still rise? You can safely demonstrate this if you have a stand with a clamp and a lab table available. You clamp a match upside down and light the match while students observe that the flame continues to rise even with the match is clamped upside-down. Summarize that since heat rises, we can expect fires on the ground to create more heat upward than downward below the soil surface. This activity illustrates that the combination of heat rising and the insulating effects of soil on the roots of plants may limit the use of fire as a weed management tool, since roots may not receive enough heat during a fire to be killed.

Adapted with permission from *FireWorks Curriculum*, USDA Forest Service

PROCEDURE

1. Place the thermocouple or digital thermometer on a table.

2. Plug in the hair dryer.

3. Each 5 pages of newspaper represents one layer of soil. The brown cloth represents the surface of the soil.

4. Go through the procedure the first time with only the brown cloth covering the thermometer. Then repeat the procedure using additional newspaper layers (increasing each experiment by 5 pages each time a "soil layer" is added) under the brown cloth. Use one full data sheet each time the insulating layers thickness is changed, recording the number of soil layers used at the top of the data sheet.

5. Assign students to the following tasks:

   Heater: Hold the hair dryer 5 cm from the surface of the table where the thermometer is located (he or she should measure the distance with a 5-cm ruler). Keep this distance constant, no matter how much insulation (5 pages of newspaper represents one soil layer) is placed between the "soil" surface (brown fabric representing the top layer of soil) and the thermometer itself. Turn on the hair dryer on high when the Timer says "Go!" Run the dryer for 15 seconds then turn it off.

   Timer: Begin timing the experiment as you call out "Go," which indicates that the Heater is to turn on the hair dryer. Call out "time" every 15 seconds during the 4-minute experiment, as follows: "Go"... then "15"... "30"... "45"... "1 minute"... "15"... "30"...

   Reader: Quickly read and call out the "official" temperature each time the timer calls out "time," being careful to keep the sensor under the insulating layers as you take the reading. This will be every 15 seconds throughout the 4 minutes.

   Recorder: Record the temperature at start of experiment and each time a temperature is called out by the Reader, which will be every 15 seconds throughout the 4 minutes. For the class demonstration, record the temperatures on a transparency of the chart for the entire class to see on the overhead projection.

6. Ask students to graph the data, with "Time" in 15-second intervals on the Y-axis and "Temperature" on the X- axis. To compare the data based on soil thickness (insulating layers), use different colored data points and connecting lines, being sure to label each color with the number of soil layers being represented.

Extensions

1. If your class does this activity in teams, treat each set of student data as a replication of the experiment for the specific soil layers used. Calculate the average values, then graph the results. Discuss this graphed data summary with the class. Here are some possible lead questions:

a) In what ways is the graph of averages more useful or more informative than the individual graphs?

b) What information is lost in the graph of averages?

c) Are there ways to show "lost" information on the graph of averages?

d) Do any of the averages seem affected by "outlier" data points, data that seem unreasonable and might be observational errors?

e) What should a scientist do with "outlier" data?

continued on page 247

7. Ask the class to try to explain the results of the graph.
(Teacher Help: Encourage students to notice that the thinner the insulation, the faster the temperature rises and the higher it goes. The thicker the insulation, the slower the temperature rises and falls; in fact, the temperature may continue to rise even after the heat source—hair dryer—is removed.)

EVALUATION

Does thick soil protect the roots from ground fire? Do you think that fire is a useful tool for weed control, and if so, when? Explain your answers fully.

Teacher Help: Surface fires usually burn quickly, and thick soil keeps the temperature below the ground surface from rising very fast. Ground fires burn very slowly. A ground fire may also heat the soil enough that many roots are killed.

Extensions, *continued*

2. Take the class on a field trip to a burned area that is adjacent to a similar area that did not burn. Make sure you know when the fire occurred, and what caused the fire. This could be a field that was burned intentionally for agricultural purposes, a lightning-caused wildfire, an accidental roadside fire, or even a prescribed burn in a local forest or prairie. Compare plant growth, with special attention to weed species and where they are found, and evidence of animal use between the burned and unburned areas. Predict what will occur over time if left alone, and brainstorm how the burned site could be managed for optimum agricultural use, wildlife habitat or other goal.

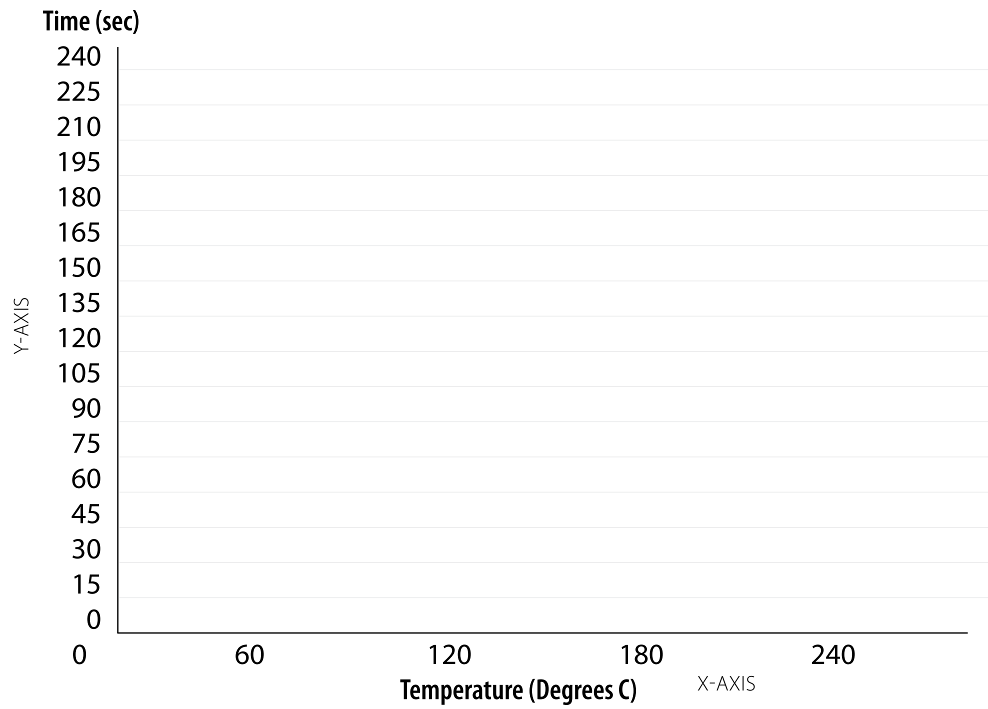
Name ______________________________

Burning Questions Data Sheet

Layers of Soil Insulation (circle one): 0 4 6 8 10

Time (sec)	**Root Temperature (Degrees C)**
0	
15	
30	
45	
60	
75	
90	
105	
120 (2 min.)	
135	
150	
165	
180 (3 min.)	
195	
210	
225	
240 (4 min.)	

Now use your graph paper to graph the above data.
Use Time for the Y-axis and Temperature for the X-axis as follows:



LESSON 43

Getting Control of the Weed Problem

OBJECTIVES

The students will: know how plants reproduce; be able to explain chemical, mechanical, fire and biological weed control methods; be able to design and conduct an experiment to simulate a weed control method; understand the problem with applying only one control method; and be able to explain what is meant by Integrated Weed Management.

METHOD

Students investigate weed control methods through individual or small group experiments.

MATERIALS

- ✎ A variety of living invasive plants and/or their seeds from schoolyard or local area.
- ✎ A plant that regenerates vegetatively and planting materials (see ***Procedure*** for details)
- ✎ A set-up with grow lights, small greenhouse, or sunny south-facing window location.
- ✎ kNOweeds Journal or a notebook for recording information.
- ✎ Copies of the following forms which are included in this lesson:
    - **Teacher's Outline for a Student Inquiry**
    - **Design-An-Experiment Form**
    - **Creating a Record of Your Weed Control Experiment**

Students will be designing their own experiments, so the materials they will use will vary. Complete materials and procedures outlines are important to experimental design and should be approved by the teacher.

BACKGROUND

The need to control weeds persists unless restoration of a healthy environment also becomes part of the solution. Pulling weeds may slow their spread, but it does not alter the conditions that first favored the invasion. Non-native weed species have the advantage of few natural enemies and an ability to persist in a wide range of habitat and environmental conditions. For these reasons, it is rare that a single method of control is effective. Land managers have a variety of means for controlling invasive weeds – chemical, biological, mechanical and fire. In this activity, students will become familiar with the process of experimental design as they create innovative solutions to controlling invasive weed species. Land managers often use a combination of several methods. Many questions remain about how best to control weeds, and there are probably as many solutions as invasive plants have adaptations to thwart our efforts. Students

Grade level: 6-8
Subject Areas: Life science
Duration: Several sessions as a class, plus up to 8 weeks for experiments
Setting: Indoors/Outdoors
Season: Fall, Spring
Conceptual Framework Topics: Integrated weed management, weed control, plant ecology, plant life cycle

This lesson was adapted with permission from *Aliens in Your Neighborhood*, a project of the National Park Service and the Upper Columbia Basin Network will have the opportunity to explore and invent some possible solutions…who knows, maybe some of them will create solutions which will be adopted by land managers, and thus turn their education into a meaningful contribution as citizen scientists.

In this activity students will perform basic research on what is currently known about the invasive weed of their choice, and then design a hypothesis and experiment that will allow them to investigate their own ideas. The activity begins with an "I wonder…" statement; for example, "If cheatgrass isn't killed by a forest fire, I wonder if freezing it would work?" You can allow ideas as broad and as wild as students can create, as long as consideration is given to safety and what resources are readily available.

After the "I wonder…" statement the students should be guided through the **Experiment Design Form**. Doing research on the question is often helpful in refining the question. The *independent variable* (the thing being manipulated, e.g. temperature), the *dependent variable* (the thing you believe will respond to the independent variable, e.g. germination rate), the *controlled variables* (those things you hold constant, e.g. humidity) and the *control* (the "normal" situation without manipulating variables so you have something to compare your results against) are part of the experiment design. Students must do a certain amount of research before they can start imagining the variables. The more refined their question, the easier it will be to determine, and limit, the variables. The fewer the variables in an experiment, the less chance for error, and the more reliable the data.

PROCEDURE

1. Obtain a plant for a class demonstration. Select a plant that naturally regenerates from rhizomes, stem sections and tap roots. Canada thistle, bindweed, or leafy spurge are some weeds that may be locally available, or you can use a house plant such as a geranium for demonstration purposes. Make sure the plant is alive and planted in a garden pot, displayed prominently at the beginning of class. Hidden from view, have a tray of moist potting soil that has been "spiked" with a small amount of fertilizer and rooting hormone. Ask your students for suggestions on how you might kill the plant and list their (appropriate) suggestions on the board. After making the list, jerk the plant out of the pot and ask how many of the students think you just killed the plant. Break a few limbs off and tear up some leaves. Do any students think it is dead yet? Pull out some scissors and snip the limbs and roots into 2-3" sections and ask the students if they think the plant is dead. At this point pull out the tray of soil, bury all the plant parts about ½" deep, mist the surface thoroughly with

water, and as you walk it over to the growing station remark, "Well, it might look dead, but I sure don't think it's dead." (In a few days, after maintaining moisture and 24 hours a day of light, you should have new sprouts from the segments of the original plant).

2. The students will design an experiment to "kill" an invasive weed species. Some suggested ways to kill a weed might be:

- Applying chemical treatment (herbicides, fungicides or pesticides)
- Simulate a wildfire
- Mechanical destruction (chopping, grinding, etc.)
- Defoliation
- Biological control
- Grazing (have a pet goat at school!)
- Compost or bury
- Cover (e.g. black plastic)
- Other?

Live plants may be transplanted from the field or started from seed, depending upon availability and time constraints. Students should record important information concerning their plant in their journals or notebook, including:

- Species name
- Date collected or planted
- Drawings of their plant
- Identification of plant parts
- Measurement of plant
- Other observations while caring for them pre-experiment

While caring for their plants the students should be conducting research about their plant and the control methods they are planning to investigate. Assist them with filling out the Experiment Design Form. Once they have most of the elements decided, they should begin writing a detailed procedure for their experiment. It is difficult for them to do this because they need to visualize an entire process that they have not yet done and are only just inventing. Explain that scientists are continually changing or modifying their procedures.

Approve their materials list and procedural outline before allowing them to begin. The first few days will be spent gathering materials and creating their set-up. Once their experiments are up and running the time spent to monitor them is reduced. Students should be encouraged to come immediately to class, collect data, and care for their plants; 10-15 minutes is usually enough. They are 100%

responsible for all aspects of their experiment – caring for the plants, collecting and recording data, updating their journal, modifying procedures, adding to their research paper, designing data collection forms, and thinking ahead to the presentation of their findings to the "scientific community" (their peers).

3. Compare the weed control experiments as a class and discuss the effectiveness of the methods chosen for killing weeds, and discuss how methods can be combined to increase the effectiveness of weed control, also know as integrated weed management or IPM (integrated pest management). Discuss how additional experiments could be designed to study the effectiveness of combined methods of weed control.

RESOURCES

U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (2003, June).
Fire Effects Information System (FEIS)
http://www.fs.fed.us/database/feis/

U.S. Department of Agriculture,
National Plant Data Center
http://plants.usda.gov/

TEACHER'S OUTLINE FOR STUDENT INQUIRY

Step 1: The Research Question (1 session)

1. Have the students write an "I wonder…" statement of some control method that would be effective for the invasive weed species they have selected.

2. Group the "I wonder…" questions into similar themes based upon control methods (chemical, biological, mechanical, fire or other).

3. Create scientific teams based upon the various themes and provide each team with an experiment that addresses each theme (or alternatively, students may work individually).

Step 2: Experimental Design (1 session)

Have the scientific teams identify the following elements for their experiment:

1. Independent and dependent variables
2. Controls
3. Hypothesis
4. Data Collection

Step 3: Review of the Literature (3 to 5 sessions plus homework)

Have the students conduct a review of the literature to find out what has been published about their particular topic, and prepare a report. Students will include copies of the sources of their information (not a reference list, but the actual articles… this will assist you with assessing their reports to help them with the difference between peer-reviewed scientific literature and conjecture, as well as plagiarism and paraphrasing).

Step 4: Conduct the Experiment

(6-8 weeks, 10-15 minutes/day to record data)

Students will assemble the materials and supplies for their experiment, provide a detailed procedure for the experiment, conduct the experiment, and design a data collection process.

Step 5: Reporting

Research details, procedures refinements, etc. should be updated regularly. Students will write a "scientific paper" to report the results of their experiment to the "scientific community" (the class) and provide a summary in an oral presentation. The scientific paper will include:

1. A title page with the name of the project, your name, and date

2. What you learned from the research

3. Copies of the resources you used

4. A description of the experiment you conducted, including independent and dependent variables, the control, problems with the experiment (sources of error), and the hypothesis you were testing.

5. An interpretation of the data collected from your experiment, including:
   a. how you collected the data
   b. a display of the data (charts, transparencies, etc.)
   c. what the data tells you
   d. whether or not your hypothesis was supported

6. Implications of the experiment (new questions that came up, how the information found can be used)

7. Any photos or drawings that help illustrate what you did

Name ______________________________ **Date** ______________

Design an Experiment

Research Topic (describe in as much detail as possible):

1. Identify the independent (manipulated) variable: ______________________________

2. Identify the dependent (responding) variable: ______________________________

3. Come up with a research question: ______________________________

   ____

4. State your hypothesis: ______________________________

   ____

5. Describe the materials you will need to do the experiment:

6. On the back of this form, or a separate sheet of paper, write a procedure to test your hypothesis. Remember to include safety considerations and details of set-up.

7. Identify your control:

8. Describe the variables that you will hold constant:

9. On a separate sheet of paper, design a data table to collect and display your results:

10. What kind of graph or chart will you use to present your data?

11. Be ready to graph your data on graph paper. Include a title, labels, and units for the vertical and horizontal axis.

12. Describe the results of your experiment. Did it answer your question? Did it support or disprove your hypothesis? Do you need to re-design the experiment and try again?

Name ____ **Area of Research** ________________________

Creating a Record of Your Weed Control Experiment

Check off each component of your experiment as it is completed.

______ "I wonder…" question.

______ A report of the research including:

1. A title page with the name of the project, your name, and date
2. A summary of the science you learned from the research
3. Copies of the resources you used
4. The following subjects should be addressed:
   - Botanical description
   - Life cycle of the weed species
   - Classification
   - Adaptations
   - Known control methods

You may have already written an initial report about your plant. However, as you become involved with your experiment you may learn more and add to your report.

______ A description of the experiment you conduct, including:

1. Independent and dependent variables
2. The control
3. Problems with the experiment (sources of error)
4. Hypothesis you were testing
5. Detailed procedures
6. Examples of the data collection sheet (preferably done in table form)

The procedures should be very detailed – a step-by-step outline of everything you have done or will be doing, including a materials list. This is another part of the project that will change and need to be updated regularly as you encounter problems or changes to your experiment/research.

______ An interpretation of the data collected from your experiment, including:

1. How you collected the data
2. The data (charts, transparencies, etc.)
3. What the data tells you
4. Whether or not your hypothesis was supported
5. Implications of the experiment (what new questions arise and how would you
6. Use the information gained from the experiment to learn more)
7. Any photos or drawings that help illustrate what you did

______ A daily journal that details what you did each day, things you've learned, problems encountered, how you resolved those problems and/or altered the design and procedures, your feelings about the process (frustrations, confusing moments, feelings of success, etc.).

All of the above components will be included along with your final typed research report.

LESSON 44

The Restoration Cycle

Grade level: 2-5
Subject Areas: Life science, ecology
Duration: 1 class session with follow-up
Setting: Outdoors/Indoors
Season: Any
Conceptual Framework Topics: Integrated weed management, weed control, habitat restoration, plant biology

OBJECTIVES

Students will be able to describe the seasonal cycle of plant restoration and explain the importance of long-term, continuous restoration planning.

METHOD

Students will develop posters representing the cyclical (seasonal) nature of restoration work. The poster can serve as a timeline and display of the restoration project process. *This lesson could be used for planning a weed removal/restoration project as part of* ***Lesson 41: Pulling Together*** *in this guide, or other class restoration project.*

MATERIALS

- ✎ Glue
- ✎ Tape
- ✎ Markers, crayons and other art supplies
- ✎ Scissors
- ✎ Poster paper
- ✎ Previously pressed weeds & native plants
- ✎ Props or pictures that represent seasonal weather, restoration work, tools, and plants.

BACKGROUND

In order to restore a natural area, it is important to develop a restoration plan, which includes specifying what the goals are, including what the desirable plant population is for the site. For example, if the goal is to restore a natural area to a similar plant diversity it had before weeds invaded the area, you will need to identify which plants occurred naturally on site and in what relative proportions, what needs to be done before these plants can be re-established (such as weed removal, soil amendment, erosion control), and how the plants will be re-established.

In Montana, restoration work is often planned around the following activities and seasons:

- Propagation (the production of more plants by seeds, cuttings, grafting or other methods. Greenhouses are often used): Fall, Winter
- Planting: Fall, Spring
- Flowering: Spring, Summer
- Seed Collecting: mid-Summer to late Summer

PROCEDURE

1. Collect the necessary poster supplies from the materials section.

2. Identify a local natural area that is invaded by weeds to use as the example for this lesson. Find out what native plants are desirable for the site, and what weeds should be removed from the site. Ask students to find out the following about these plants:

- What is the best way to propagate this native plant?
- When is the best time to plant this native plant outdoors?
- At what time of the year does this plant flower?
- When is the best time to collect this native plant's seeds?
- What are the best ways and best times of the year to remove this weed?
- How can we control this weed long-term?

(See the ***Resources*** *section of this guide for sources of information)*

3. Explain to students that we will look at how we can help restore lands year-round, and then create a Restoration Cycle Calendar for display, which can be used to plan a restoration project for our selected site or for an imaginary one.

4. Ask Students: What is a *restoration cycle*?
Teacher Help: Start by dividing the term up and defining. ***Restoration:*** *To return and improve the ecological health of an area or habitat.* ***Cycle:*** *A series of events that repeat themselves so that they are never ending.*

5. Ask students to list the four seasons. For each season have students imagine/list what the weather is like and what is happening in the life cycle of the plants in our local ecosystems. Have students also list what types of restoration work can be done during each season.

Teacher Help: ***Montana Seasons***

Late Fall, early Winter *– snowy, windy, wet, cold*

Move trays/pots of planted seeds outdoors to overwinter or plant seeds that need cold treatment in ground before it is too frozen to plant.

Continue to care for indoor plantings.

Spring *- rainy, windy, sunny, cool*

The natives are germinating and growing, some natives flower. Make plant pressings of flowers. Take pictures.

Make room for native plants - Clear out invasive plants before they can flower and go to seed and increase the seed bank.

***Summer** - dry, sunny, warm*

Seeds are produced.

Collect native seeds to plant later.

Remove the weed plants and seeds to prevent future weeds.

***Fall** – sunny to rainy, warm to cold*

Sow the native seeds in flats/pots. If they need cold treatment, move outdoors; if not, grow in greenhouse or other suitable location.

Prepare soil at site for planting and propagation.

6. Explain to students that we are going to construct and decorate a cyclical calendar of restoration for a local site we would like to restore (one that has been invaded by weeds, is suitable for native plant restoration, and can be watered and cared for regularly by the class). Distribute poster-making materials. Have students:

- Design and decorate a central poster labeled "The Restoration Cycle."
- Label the cycle goals (i.e. weed removal, propagation, planting, etc.) that correspond with each season on separate sheets of poster paper.
- Feature certain species of weeds and natives that are significant to a particular season in the posters.
- Focus on the times that are best for collecting seed and propagating particular native plants.
- Focus on the times and methods that are best for removing unwanted plants.

7. Divide the class into four teams (1 team for each season) and have students create a poster to depict what the site looks like before restoration, during the restoration, and once the project is complete- this is a depiction of the restoration cycle for their chosen site. They can decorate their own posters using various media. Students could include plant pressings and photographs. Encourage students to be creative.

8. *Note:* Remind students that we will continue to add to the posters in the future. If students have an idea or contribution that may take more time to work on, use it as a platform for returning to the cycle.

9. Have students present their poster to others. In their description ask students to explain what a restoration cycle is and what needs to be done during their season. Have students explain why it is important to plan ahead for their season.

Extensions

1. Have students explain what might happen if the restoration cycle is broken. How could it be broken? What would be lost?

2. Using the Restoration Cycle posters developed for this lesson, embark on a class restoration project. You may want to follow the steps in ***Lesson 41: Pulling Together*** in this guide if you plan to use weed pulls for weed removal on your selected site.

LESSON 45

Managing Invasive Plants

OBJECTIVES

Students will understand that weed management is a complex issue that may require many different kinds of actions. They will realize that different people have different viewpoints about how to manage weeds, and that appropriate management may differ depending on the desired outcomes and the place.

METHOD

Students brainstorm and discuss factors contributing to weed invasions and efforts that can help control weeds. They read about different perspectives on weeds and weed management, and may conduct their own interviews of people in their area. They develop their own weed management plan based on their knowledge of control methods and the desired outcomes for the area.

MATERIALS

✎ **Integrated Plant Management (IPM) flowchart worksheet**
✎ **Integrated Plant Management (IPM) Options Chart**
✎ **Weed Management Plan Template**

BACKGROUND

Why Are Weeds a Problem?

The spread of invasive non-native plants is a serious environmental problem in North America. Controlling them costs ranchers, farmers, conservation groups, utility companies, governments, and citizens millions of dollars each year. It has been estimated that the economic impact of leafy spurge in Montana, North and South Dakota, and Wyoming totals $129.5 million each year and may result in the loss of 1,433 jobs. In Montana alone, spotted knapweed is estimated to cost $42 million each year.

The list of problems weeds can cause is long:

- ***They can displace native plants,*** including rare and endangered species.

- ***Invasive plants can diminish wildlife habitat*** by reducing forage, cover, and water availability. These changes can affect a variety of fauna, from soil organisms, invertebrate and vertebrate pollinators, herbivores, and seed-eaters, to the predators which feed on all of these. For example, research shows decreased use by ungulates of areas with heavy infestations of knapweed and spurge. In Montana, rare plants threatened by invasive plants include Sapphire rockcress, Missoula phlox, and Ute ladies'-tresses.

- ***Invasive plants can reduce the yield and quality of agricultural crops.*** Grazing capacities for livestock can be reduced 65% to 90% by weed invasions. Weeds cost farmers in Montana over $100 million each year in expenses and reduced crop production.

Grade level: 5-8
Subject Areas: Biology, writing, technology, social studies
Duration: Several class sessions, plus travel time to field sites.
Setting: Classroom and field site(s)
Season: Fall, Spring or Summer to observe field sites; anytime for classroom work.
Conceptual Framework Topics: Invasive plant management, weed management plans, career exploration, taking action

Leafy Spurge
Euphorbia esula

- ***Invasive plants can increase soil erosion and stream sedimentation.*** In one study, runoff was 1.5-times higher and sediment was 3 times higher on spotted knapweed-dominated plots than on plots dominated by the native bluebunch wheatgrass (Montana's state grass). Increased runoff tends to result in greater loss of soil and increased sedimentation in streams.

- ***Some invasive plants are toxic to humans, pets, livestock, and wildlife.*** They may irritate the skin or cause sickness or death if eaten by animals.

- ***Invasive plants may lower recreational values.*** Many invasives cause unpleasant conditions for recreation, due to prickliness (thistles, knapweed), burrs (houndstongue), access for boating, fishing and swimming (Eurasian watermilfoil) and simply by displacing the native vegetation and fauna that enhance outdoor experiences.

- ***Invasive plants can alter the water table and impact riparian areas.*** Tamarisk (saltcedar), which has invaded riparian areas and wetlands throughout the country, including eastern Montana, uses much larger quantities of water than native species. This lowers water tables and, in some areas, has eliminated surface water and native vegetation. Saltcedar infestations can affect carrying capacities and flooding cycles of waterways.

Why are many weeds difficult to control?
Successfully invading species tend to have one or more of the following characteristics:

- They reproduce quickly by producing many seeds.
- Their seeds may remain viable for several years.
- They grow quickly.
- They are able to spread vegetatively (that is, through their roots or pieces of the plant).
- They have deep roots (leafy spurge roots can reach 20 feet in length!).
- They are not palatable to livestock and wildlife.
- They are not susceptible to local diseases, parasites, herbivores, etc.
- They are allelopathic – they give off chemicals that inhibit the germination or growth of other plants.

What is the best way to manage weeds?
The best weed management strategies to use depend on the weed species, the area, the goals for management, the resources, and many other factors. An ecologically-based, adaptive, integrated approach is usually most effective in the long run. This includes creating a management plan that assesses many aspects, and allows for monitoring the site and modification of the actions, if necessary.

It may include some or all of the following methods of weed control:

1. **Prevention:** Prevent weeds from entering an area by promoting weed-free forage, weed-free gravel, cleaning shoes and tires, minimizing disturbance to existing vegetation and soil, etc.

2. **Herbicides:** Apply chemicals such as herbicides to kill or retard the growth of weeds.

3. **Biological control:** Release or encourage natural enemies of weeds, such as insects or fungi, which kill or retard the growth or reproduction of the plants.

4. **Targeted grazing:** Use livestock under very controlled conditions to eat target plants.

5. **Mechanical:** Kill or remove plants through cutting, pulling, plowing, digging, etc.

6. **Prescribed burning:** Burn an area under controlled conditions to kill or check weeds.

7. **Revegetation:** Replant a disturbed site with desired species.

PROCEDURE

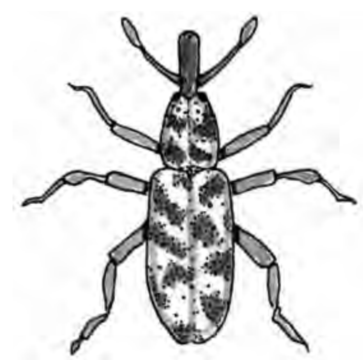
Students should be familiar with what weeds are and the basic problems associated with them, be able to identify some common Montana weeds, and create basic maps. Other lessons presented in the ***kNOweeds Curriculum Guide*** can help build this knowledge.

You might want to think ahead of time about possible sites for your students to select to create a weed management plan. This could be your own schoolyard, a nearby park or empty lot, an agricultural field, or an area of public land. You may want to have your students present their finished plan to those responsible for managing the area they select.

1. Begin the lesson by asking your students to brainstorm what problems invasive plants can cause. See if you can make a class list that covers all the issues listed above, plus any others they can come up with! Ask if they have any firsthand experience with weeds causing some of these problems. After your discussion, pass out page 1 of the **IPM Flowchart Worksheet** and ask each student to think about factors that they think might contribute to the spread of weeds where there are now native plants, crops, or other desired plants. After they fill in their page 1, discuss as a class what students come up with.

Spotted Knapweed BIOCONTROLS

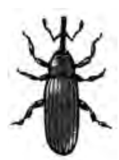
Flower Weevil
Larinus minutus
x4



Root Weevil
Cyphocleonus achates
x3

Root Moth
Agapeta zoegana
x3

Dalmatian Toadflax
BIOCONTROL



Weevil
Mecinus janthinus
x4

Now ask them to think about ways to control or manage invasive plants, using page 2 of the worksheet, and discuss. Explain that many people who manage weeds may use many or all of the methods they have listed, depending on the circumstances. Discuss the reasons that some methods may work better than others in some areas, and have them do some research to fill out the **IPM Options Chart**.

2. At this point you may want to have them contact someone in your local community to "interview" them about weed management. If possible, try to get a variety of viewpoints. Some possible perspectives to consider are those of a farmer or rancher; government land manager; a manager for a conservation organization; utility company, or highway department; a small landowner; beekeeper; gardener; native plant enthusiast, etc. Some questions they might want to consider asking include:

1. How do invasive plants affect you?
2. Have you taken action to control them? If so, what have you done?
3. Have you been able to see a change as a result of your actions?
4. How did you decide what method(s) to use to control weeds?
5. Have you considered or are you considering trying any other kind of control method?
6. How long do you think you will have to try to control weeds?
7. How much time do you spend dealing with invasive plants?

When they have conducted their interview, have them report back to the rest of the class on what they found out. They could even role-play the person they interviewed, and allow other students to ask them questions. When all students have presented their "perspectives," discuss similarities and differences among these as a class.

3. Now they are ready to select a site for which to create a weed management plan. If this hasn't already come up in discussion, explain that many people who manage weeds create a plan so that they can go about it in an organized, well-thought-out way, considering all possibilities and assessing their results.

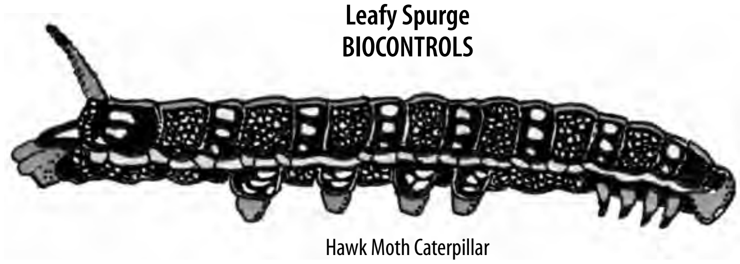
Brainstorm with them the kinds of elements they think a weed management plan might need to contain. Show them the template and brainstorm or ask them to list the kinds of information they need to collect to write their plan. You may want to decide as a class how much detail you want to go into and which parts, if any, of the plan template you don't want to use. For example, obviously they won't actually be using herbicides, but you may want them to fill in the information to make them aware of the safety concerns and legal considerations involved in using chemical controls. Assign sections to different students or pairs of students, or let them figure out how to divide up the work. You may decide to have the entire class work on one plan, or have a few different plans.

4. When students have selected a site for which to write a plan, have them visit the site to collect the information they need. This may include mapping the site and any weed populations they have found (see lessons on mapping and weed surveys in this Guide). They may also need to talk to the landowner or manager to gather supplementary information about the site (use, history, etc.).

When they know which invasive plant species are present, they may want to use a resource such as the NRCS Noxious Weed Treatment Quick Reference (**http://www.weedawareness.org/weed_poster.pdf**) to determine which methods to use.

After they have finished their plan, they can present it to the rest of the class (if there is more than one group) or to you.

Leafy Spurge
BIOCONTROLS



Hawk Moth Caterpillar
Hyles euphorbiae

Hawk Moth
Hyles euphorbiae

Brown Flea Beetle
Aphthona nigriscutis
x4

Black Flea Beetle
Aphthona lacertosa
x4

Extensions

Students may want to send a copy of the plan or present it to the landowner.

Name ____

INTEGRATED PLANT MANAGEMENT (IPM) OPTIONS CHART

Type of Control	Features of control methods				
	Rapid Response	**Short-term Effectiveness**	**Long-term Effectiveness**	**Personal Safety**	**Environmental Effects**
Prevention					
Mechanical					
Herbicides					
Biological					
Grazing					
Controlled burning					
Revegetation					

SITE WEED MANAGEMENT PLAN

FOR

____

site name, town/location

Date:______________________________

PREPARED BY: ____

____

Authors, Teacher, School, Grade(s)

INTRODUCTION

A. Description and purpose of the site. Also list important plants or animals, human uses, and your management goals.

B. Description of how certain invasive plant species ("weeds") interfere with management goals of the site.

C. Inventory of plant species that you want to control.

SUMMARY OF ACTIONS PLANNED

Use the following table to guide your plan development. List species in order of priority.

Plant Species:	Scientific name and common names
Location(s):	Map and describe where it occurs on your site.
Area (acreage):	Estimate or use GPS to determine the amount of area invaded.
Control Method(s):	What methods should you use to control it?
Schedule:	When will you do this? (Time of year, etc.)
Monitoring Plan:	How will you monitor it to make sure your efforts are successful?
Estimated Cost:	Estimate the hours and costs needed for the work you have planned.

Plant Species 1: ______________________________

Location(s): ______________________________

____

____

Area (acreage): ______________________________

Control Method(s): ______________________________

____

Schedule: ______________________________

Monitoring Plan: ______________________________

____

Estimated Cost: ______________________________

Plant Species 2: ______________________________

Location(s): ______________________________

____

____

Area (acreage): ______________________________

Control Method(s): ______________________________

____

Schedule: ______________________________

Monitoring Plan: ______________________________

____

Estimated Cost: ______________________________

Plant Species 3: ______________________________

Location(s): ______________________________

____

____

Area (acreage): ______________________________

Control Method(s): ______________________________

____

Schedule: ______________________________

Monitoring Plan: ______________________________

____

Estimated Cost: ______________________________

Plant Species 4: ______________________________

Location(s): ______________________________

____

____

Area (acreage): ______________________________

Control Method(s): ______________________________

____

Schedule: ______________________________

Monitoring Plan: ______________________________

____

Estimated Cost: ______________________________

Plant Species 5: ______________________________

Location(s): ______________________________

____

____

Area (acreage): ______________________________

Control Method(s): ______________________________

____

Schedule: ______________________________

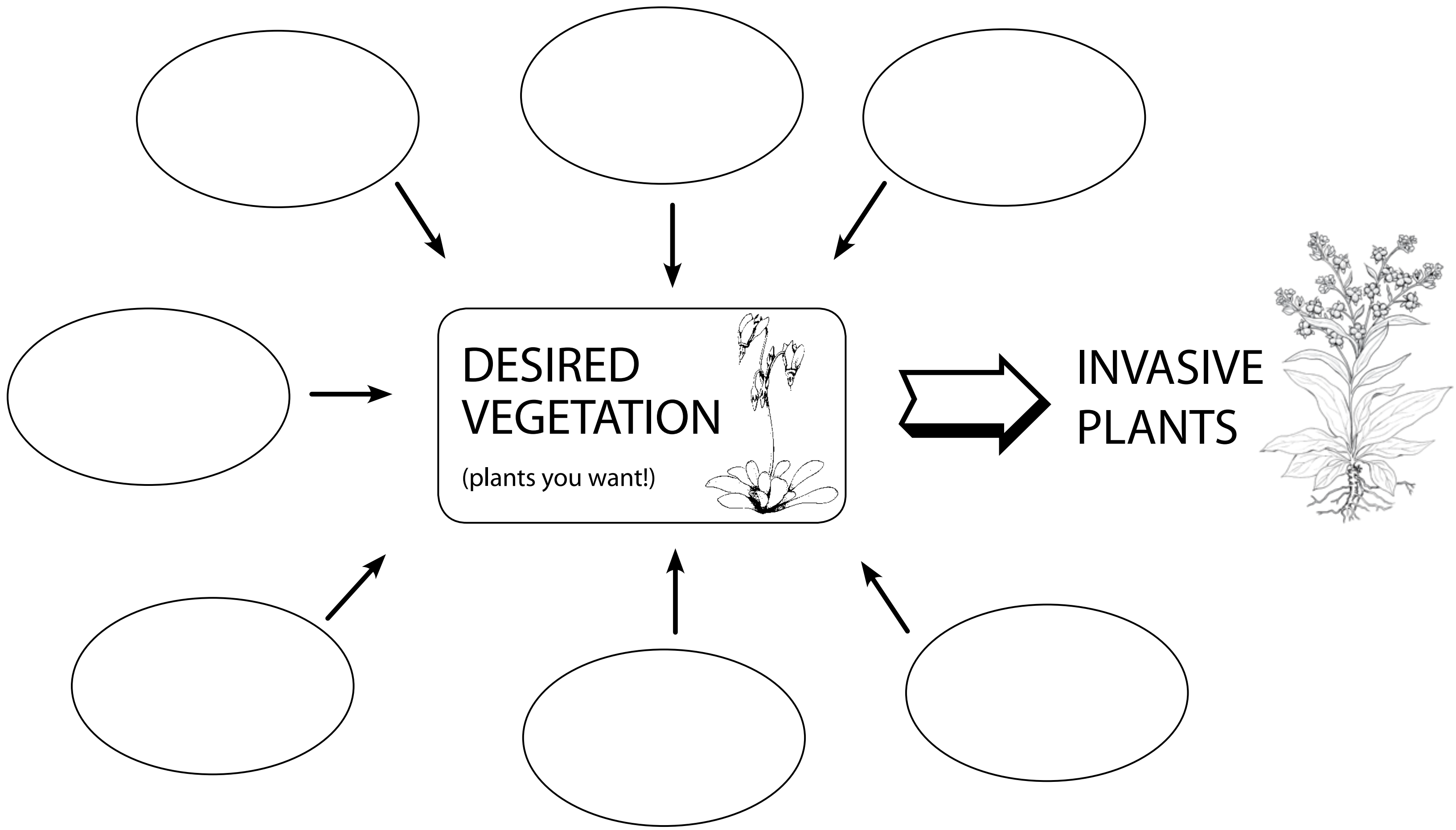
Monitoring Plan: ______________________________

____

Estimated Cost: ______________________________

1

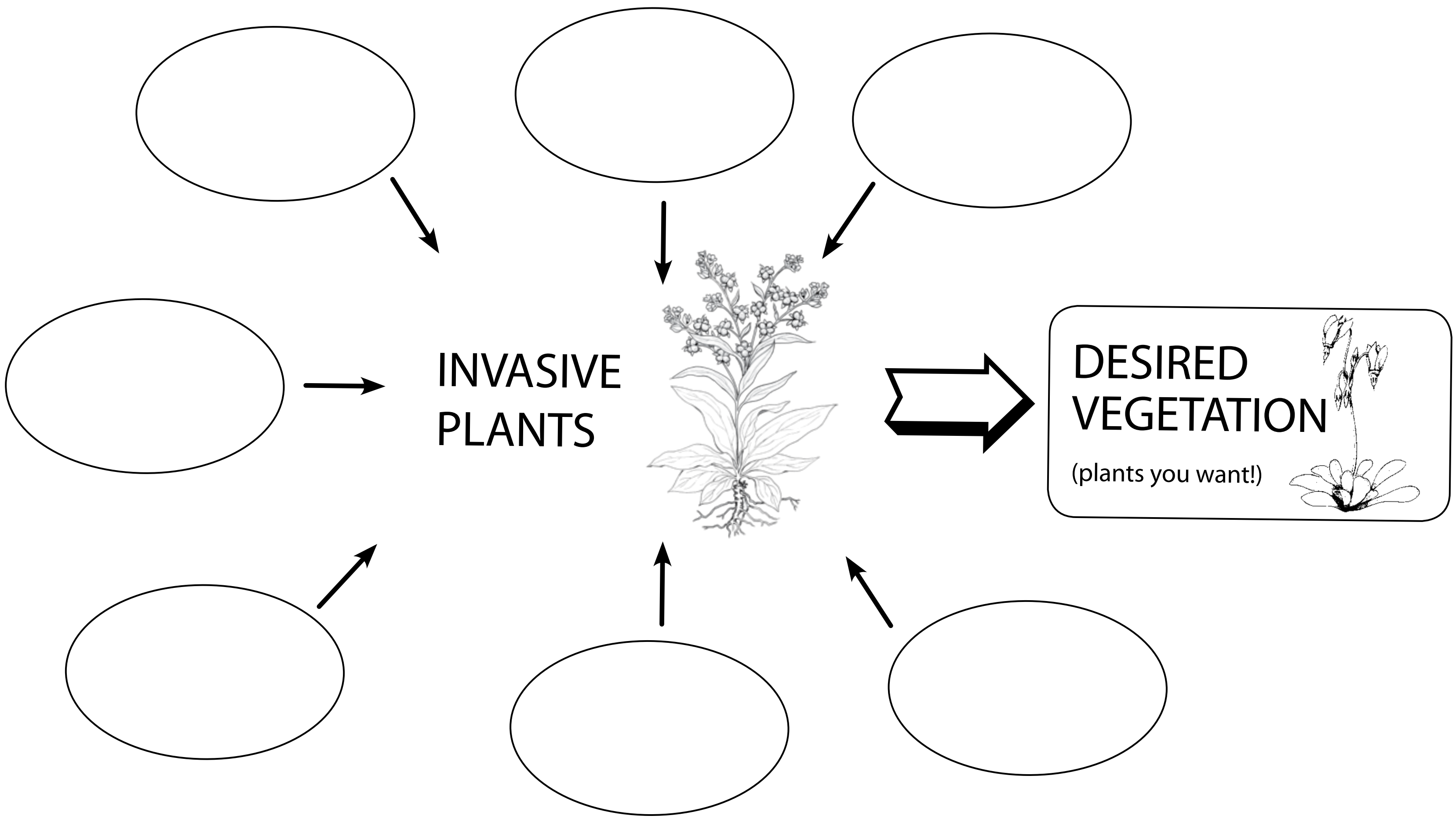
What kinds of things do you think might make it easier for non-native plants to invade an area and replace desired plants, such as native plants or agricultural plants? Can you think of human factors? Natural factors?



IPM Flowchart

2

What kinds of things might be done to decrease invasive weeds and help an area return to the desired vegetation?



IPM Flowchart

LESSON 46

Invasive Plant Management:
Plan to Action

Grade level: 9-12
Subject Areas: Biology, writing, technology, social studies, math
Duration: Several class sessions, plus travel time to field sites.
Setting: Classroom and field site
Season: Fall, Spring or Summer to observe field sites; anytime for classroom work.
Conceptual Framework Topics: Invasive plant management, weed management plans, career exploration, taking action

OBJECTIVES
Students will understand that weed management is a complex issue that may require many different kinds of actions. They will realize that different people have different viewpoints about how to manage weeds, and that appropriate management may differ depending on the desired outcomes and the place.

METHOD
Students discuss factors contributing to weed invasions and efforts that can help control weeds, using their discussions to complete concept maps on these subjects. They conduct their own interviews of people in their area with different perspectives on weeds and weed management. They develop their own weed management plan based on their knowledge of control methods and the desired outcomes for the area.

MATERIALS
- ✎ *Invasive Plant Management* PowerPoint (available on *kNOweeds* CD or at **http://missoulaeduplace.org/weeds_curriculum.shtml**
- ✎ **IPM flowchart worksheet**
- ✎ **IPM Options Chart**
- ✎ **Weed Management Plan Template** (electronic format or hard copy)
- ✎ **Weed Management Worksheet** (Excel; electronic format or hard copy)

BACKGROUND
Why Are Weeds a Problem?
The spread of invasive non-native plants is a serious environmental problem in North America. Controlling them costs ranchers, farmers, conservation groups, utility companies, governments, and citizens millions of dollars each year. It has been estimated that the economic impact of leafy spurge in Montana, North and South Dakota, and Wyoming totals $129.5 million each year and may result in the loss of 1,433 jobs. In Montana alone, spotted knapweed is estimated to cost $42 million each year.

The list of problems weeds can cause is long:
- ***They can displace native plants,*** including rare and endangered species. Some studies have shown that where spotted knapweed, leafy spurge, and other species have invaded, some native species may be reduced or eliminated in a few years' time.

Sulphur Cinquefoil
Potentilla recta

- ***Invasive plants can diminish wildlife habitat*** by reducing forage, cover, and water availability. These changes can affect a variety of fauna, from soil organisms, invertebrate and vertebrate pollinators, herbivores, and seed-eaters, to the predators which feed on all of these. For example, research shows decreased use by ungulates of areas with heavy infestations of knapweed and spurge. In Montana, rare plant species threatened by invasive plants include Sapphire rockcress, Missoula phlox, and Ute ladies'-tresses. Invasives can deteriorate habitat for fish and other aquatic organisms as well.

- ***Invasive plants can reduce the yield and quality of agricultural crops.*** Grazing capacities for livestock can be reduced 65% to 90% by weed invasions. Weeds cost farmers in Montana over $100 million each year in expenses and reduced crop production.

- ***Invasive plants can increase soil erosion and stream sedimentation.*** In one study, runoff was 1.5-times higher and sediment was 3 times higher on spotted knapweed-dominated plots than on plots dominated by the native bluebunch wheatgrass (Montana's state grass). Increased runoff tends to result in greater loss of soil and increased sedimentation in streams.

- ***Some invasive plants are toxic to humans, pets, livestock, and wildlife.*** They may irritate the skin or cause sickness or death if eaten by animals.

- ***Invasive plants may lower recreational values.*** Many invasives cause unpleasant conditions for recreation, due to prickliness (thistles, knapweed), burrs (houndstongue), and simply by displacing the native vegetation and fauna that enhance outdoor experiences.

- ***Invasive plants can alter the water table and impact riparian areas.*** Tamarisk (saltcedar), which has invaded riparian areas and wetlands throughout the country, including eastern Montana, uses much larger quantities of water than native species. This lowers water tables and, in some areas, has eliminated surface water and native vegetation. Saltcedar infestations can affect carrying capacities and flooding cycles of waterways.

Why are many weeds difficult to control?

- Successfully invading species tend to have one or more of the following characteristics:
- They reproduce quickly by producing many seeds.
- Their seeds may remain viable for several years.
- They grow quickly.
- They are able to spread vegetatively (that is, through their roots or pieces of the plant).

- They have deep roots (leafy spurge roots can reach 20 feet in length!).
- They are not palatable to livestock and wildlife.
- They are not susceptible to local diseases, parasites, herbivores, etc.
- They are allelopathic – they give off chemicals that inhibit the germination or growth of other plants.

What factors help weeds invade?

1. Seed introduction by animals, humans, or vehicles such as bikes or cars moving from weedy to non-weedy areas, or seeds traveling in animal feed or with other seeds.

2. Removal or disturbance of existing vegetation and soil through trampling, driving, development, road-building.

3. Overgrazing by wildlife or livestock.

What is the best way to manage weeds?

The best weed management strategies to use depend on the weed species, the area, the goals for management, the resources, and many other factors. An ecologically-based, adaptive, integrated approach is usually most effective in the long run. This includes creating a management plan that assesses many aspects, and allows for monitoring of the site and modification of the actions, if necessary. It may include some or all of the following methods of weed control:

1. **Prevention:** Prevent weeds from entering an area by promoting weed-free forage, weed-free gravel, cleaning shoes and tires, minimizing disturbance to existing vegetation and soil, etc.

2. **Herbicides:** Apply chemicals such as herbicides to kill or retard the growth of weeds.

3. **Biological control:** Release or encourage natural enemies of weeds, such as insects or fungi, which kill or retard the growth or reproduction of the plants.

4. **Targeted grazing:** Use livestock under very controlled conditions to eat target plants.

5. **Mechanical:** Kill or remove plants through cutting, pulling, plowing, digging, etc.

6. **Prescribed burning:** Burn an area under controlled conditions to kill or check weeds.

7. **Revegetation:** Replant a disturbed site with desired species.

PROCEDURE

Students should be familiar with what weeds are and the basic problems associated with them, be able to identify some common Montana weeds, and know how to create basic maps. Other lessons presented in the ***kNOweeds Curriculum Guide*** can help build this knowledge.

Think ahead of time about possible sites for your students to select for which to create a weed management plan. This could be your own school grounds, a nearby park or empty lot, an agricultural field, or an area of public land. You may want to have your students present their finished plan to those responsible for managing the area they select.

1. Using either the *Invasive Plant Management* PowerPoint or a discussion format, begin the lesson by asking your students to think about the factors that may make it easier for invasive species to colonize an area and displace native or other desired plants. You may want to pass out page 1 of the **IPM Flowchart Worksheet**. After they fill in their page 1, discuss as a class what students came up with.

2. Now ask them to think about ways to control or manage invasive plants, using page 2 of the worksheet, and discuss. Explain that many people who manage weeds may use many or all of the methods they have listed, depending on the circumstances. Go through the rest of the PowerPoint on Integrated Plant Management. Discuss the reasons that some methods may work better than others in some areas, and have them do some research to fill out the **IPM Options Chart**.

3. At this point you may want to have them contact someone in your local community to "interview" them about weed management. If possible, try to get a variety of viewpoints. Some possible perspectives to consider are those of a farmer or rancher; government land manager; a manager for a conservation organization; utility company, or highway department; a small landowner; beekeeper; gardener; native plant enthusiast, etc. Some questions they might want to consider asking include:

- How do invasive plants affect you?
- Have you taken action to control them? If so, what have you done?
- Have you been able to see a change as a result of your actions?
- How did you decide what method(s) to use to control weeds?
- Have you considered or are you considering trying any other kind of control method?
- How long do you think you will have to try to control weeds?
- How much time do you spend dealing with invasive plants?

4. When they have conducted their interview, have them report back to the rest of the class on what they found out. They could even role-play the person they interviewed, and allow other students to ask them questions. When all students have presented their "perspectives", discuss similarities and differences among these as a class.

5. Now they are ready to select a site for which to create a weed management plan. If this hasn't already come up in discussion, explain that many people who manage weeds create a plan so that they can go about it in an organized, well-thought-out way, considering all possibilities and assessing their results. Brainstorm with them the kinds of elements they think a weed management plan might need to contain. Show them the template and brainstorm or ask them to list the kinds of information they need to collect to write their plan. You may want to decide as a class how much detail you want to go into and which parts, if any, of the plan template you don't want to use. For example, obviously they won't actually be using herbicides (see Appendices 4-6 in the template), but you may want them to fill in the information to make them aware of the safety concerns and legal considerations involved in using chemical controls. Assign sections to different students or pairs of students, or let them figure out how to divide up the work.

6. When a site has been selected and it's been decided what kind of information they need, have them visit the site to collect any pertinent information. This may include mapping and the site and any weed populations they have found (see other lessons in the ***kNOweeds Curriculum Guide*** for help with this). They may also need to talk to the landowner or manager to gather supplementary information about the site (use, history, etc.).

7. After they have finished their plan, they can present it to the rest of the class (if there is more than one group) or to you. Work with them to refine the plan and figure out if there are unworkable or impractical parts. If possible, have your students begin to implement it or work with those responsible for managing the site to do so!

Extensions

Students may want to send a copy of the plan or present it to the landowner.

Name ______________________________

INTEGRATED PLANT MANAGEMENT (IPM) OPTIONS CHART

Type of Control	Features of control methods				
	Rapid Response	Short-term Effectiveness	Long-term Effectiveness	Personal Safety	Environmental Effects
Prevention					
Mechanical					
Herbicides					
Biological					
Grazing					
Controlled burning					
Revegetation					

SITE WEED MANAGEMENT PLAN

FOR

____

site name, town/location

Date:___________________________

PREPARED BY: ____

____

Authors, Teacher, School, Grade(s)

1. INTRODUCTION

A. Description and purpose of the site

State what kind of site you want to manage (agricultural, park, schoolyard, recreation, etc.) Also briefly describe:

1. Distinctive biological communities (for example, Ponderosa Pine forest, grassland, alfalfa field, etc.)
2. Land-use histories (grazing, logging, recreation, etc.)
3. Important plants or animal in the management area
4. Management goals (remove invasives, restore native plants, create productive field, etc.)
5. Any major challenges to achieving those goals

B. Description of how certain plant species ("weeds") interfere with management goals of the site. *Use this section explain why you want to eliminate or control certain plant species here. Briefly describe what problems these plants cause, or could if allowed to flourish.*

C. Inventory of plant species that you want to control

Inventory populations of weeds located on and near the site. Map these populations and estimate the area(s) they cover.

2. OVERVIEW OF WEED MANAGEMENT PLAN

A. General Management Philosophy

What main guidelines do you want to use in developing your plan? Some things to think about may include:

- What is your final goal for managing weeds at the site? Does it go beyond just removing unwanted plant species?
- What kinds of species will you focus on or set as priorities? How will you choose priority species?
- Will you consider the potential impacts of the control methods themselves? How will this factor into how you decide what methods to use?
- What other issues will you consider when choosing your management actions?
- Will you evaluate the success or failure of your plan? If so, how?
- How will you use any information you gather about how your plan is working?

Setting Priorities

The priority-setting process can be difficult, partly because you need to consider so many factors. Consider each of the following factors:

I. Current extent of the species: in the long run, it is usually most efficient to prevent problems and immediately address new invasions. Give priority to species that are present nearby or just starting to invade the site, especially if they are expanding rapidly.

II. Current and potential impacts of the species: Species that alter ecosystem processes such as fire frequency or sedimentation rates, invade undisturbed plant communities, or reduce resources such as food or nesting sites for animals should generally be given the highest priorities.

III. Value of the habitats/areas the species infests or could infest: Give priority to controlling infestations in important habitats, such as those used by rare or highly valued plants or animals.

IV. Difficulty of control and establishing replacement species: Give priority to managing species that are able to be controlled with available resources with minimum harm to desirable plants, and which can be replaced by desired plants with minimum additional resources.

B. Summary of Specific Actions Planned

Briefly (1-3 paragraphs) describe or outline your weed control plan. Note which species you plan to control, where and over what period you plan to do so, the methods you plan to use, which species you plan to monitor, and how you plan to do so. You may also briefly explain why you do not plan to control certain species.

C. Tables

Use Excel or another spreadsheet program to create a prioritized list of weed species, an implementation schedule for you plan, and the estimated costs to carry out the plan.

Table 1. Prioritized List of Weed Species

Rank species based on your priorities, using a format such as the example below.

Scientific Name	Common Name	Rank/Priority	Comments

Table 2. Weed Management Plan Implementation Schedule

Schedule the planning, surveying, and treatment for each target weed for at least the next year as the example below.

	Year 1				**Year 2**			
Target Species	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall

Codes: S=survey; T=treatment; P=plan control efforts

Table 3. Projected Resource Costs to Implement Weed Management Plan

Estimate the hours and costs needed for the work you have planned as the example below.

			Year 1	**Year 2**	
Target Species	Resource *(For example, labor, materials, transportation, etc.)*	Items/ Comments:	Estimated Cost	Estimated Cost	Total Cost

(copy this and next page for additional species)

3. SPECIFIC CONTROL PLANS FOR HIGH PRIORITY WEED SPECIES

*Scientific name:*________________________ *Common name:*___________________________

A. PRIORITY _____

B. DESCRIPTION
In 2-3 lines list habit, life history, native range, and other outstanding characteristics

C. CURRENT DISTRIBUTION ON THE SITE
Refer to maps, Section 1C.

D. DAMAGE & THREATS
Outline damage caused and threats posed by the species. Refer to Section 1B.

E. GOALS
Outline long-term goals for this species. For example, you may want to reduce numbers of this species so that it no longer threatens populations of a rare species or so that it does not affect fire frequencies on the site. You may want to list measurable objectives, such as reduce the population by 50% in 2 years.

F. MANAGEMENT OPTIONS
Viable control options are:

(1) No treatment;

(2) (Treatment alternative 1);

(3) (Treatment alternative 2).

Briefly discuss the alternatives, indicate which are preferred and the conditions (location, anticipated cost, etc.) under which they may be used.

I. HOW ACTIONS WILL BE EVALUATED (Criteria for success)
Outline the methods that will be used to monitor control activities and how success or failure of the program will be determined.

J. RESOURCE NEEDS
Estimate the amount of time and money that will be required to carry out the planned control, monitoring and evaluation for this species.

4. APPENDICES

Appendix 1. BLANK MAPS/SAMPLE MAPS

Attach copies of the map(s) of the site, and of (overlaid) maps depicting the extent of the target weed(s) on the site here.

Appendix 2. FORMS USED IN COLLECTING INVENTORY AND MONITORING DATA

Attach copies of data collection sheets here.

Use the following 3 appendices if herbicides are to be used.

Appendix 3. HERBICIDE USE PROTOCOLS

After noting which herbicide(s) will be used and roughly how much will be used, outline any state and local requirements for applicator licensing and/or posting of treated areas. Then, BRIEFLY describe how the herbicide(s) will be stored, mixed and transported. Describe how excess herbicide and any equipment or clothing that has become contaminated will be disposed of. Describe emergency first aid procedures and plans for responding to spills or contamination. List who may apply the herbicide(s), and what protective gear will be available for them.

Appendix 4. HERBICIDE USE RECORD FORMS

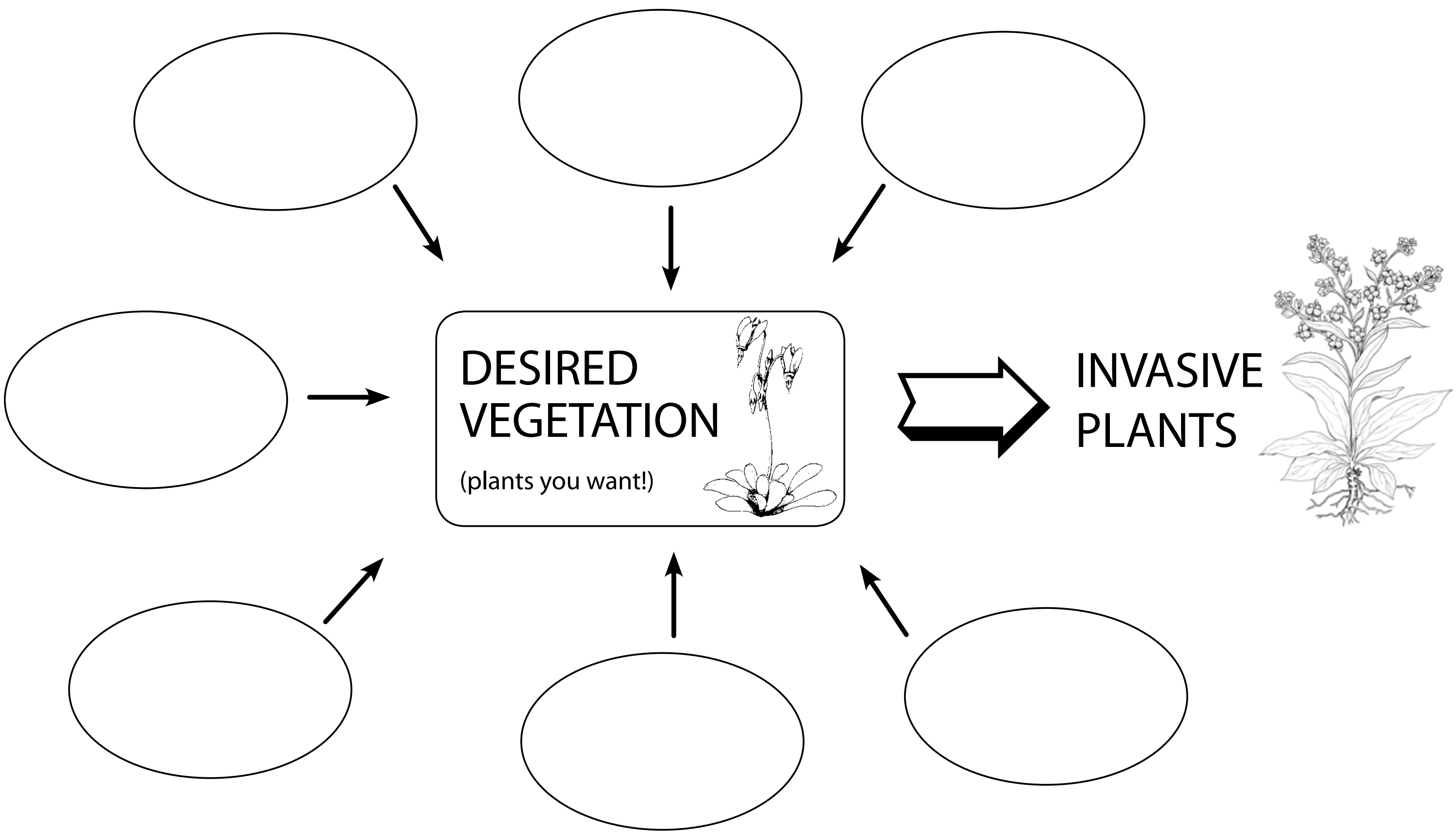
When using herbicides it is critical (and, in many cases, required by law) to keep detailed records of all relevant information. Ideally, records would include data on the condition of the site prior to herbicide application, the type of species present, and percent cover of invasive and native species prior to application. This information will be valuable in evaluating the effectiveness of the herbicide. At the time of application, take detailed notes of the type and concentration of the herbicide, the amount, location, and method of application, weather conditions, and any other observations made during the course of application. This information is important in evaluating the project's success, improving methodology, and identifying mistakes. In addition, it documents the procedure for future site managers and biologists

Appendix 5. HERBICIDE LABELS

Attach copies of the herbicide label(s) here. Herbicide labels can be found on the internet by searching for the name of the herbicide.

1

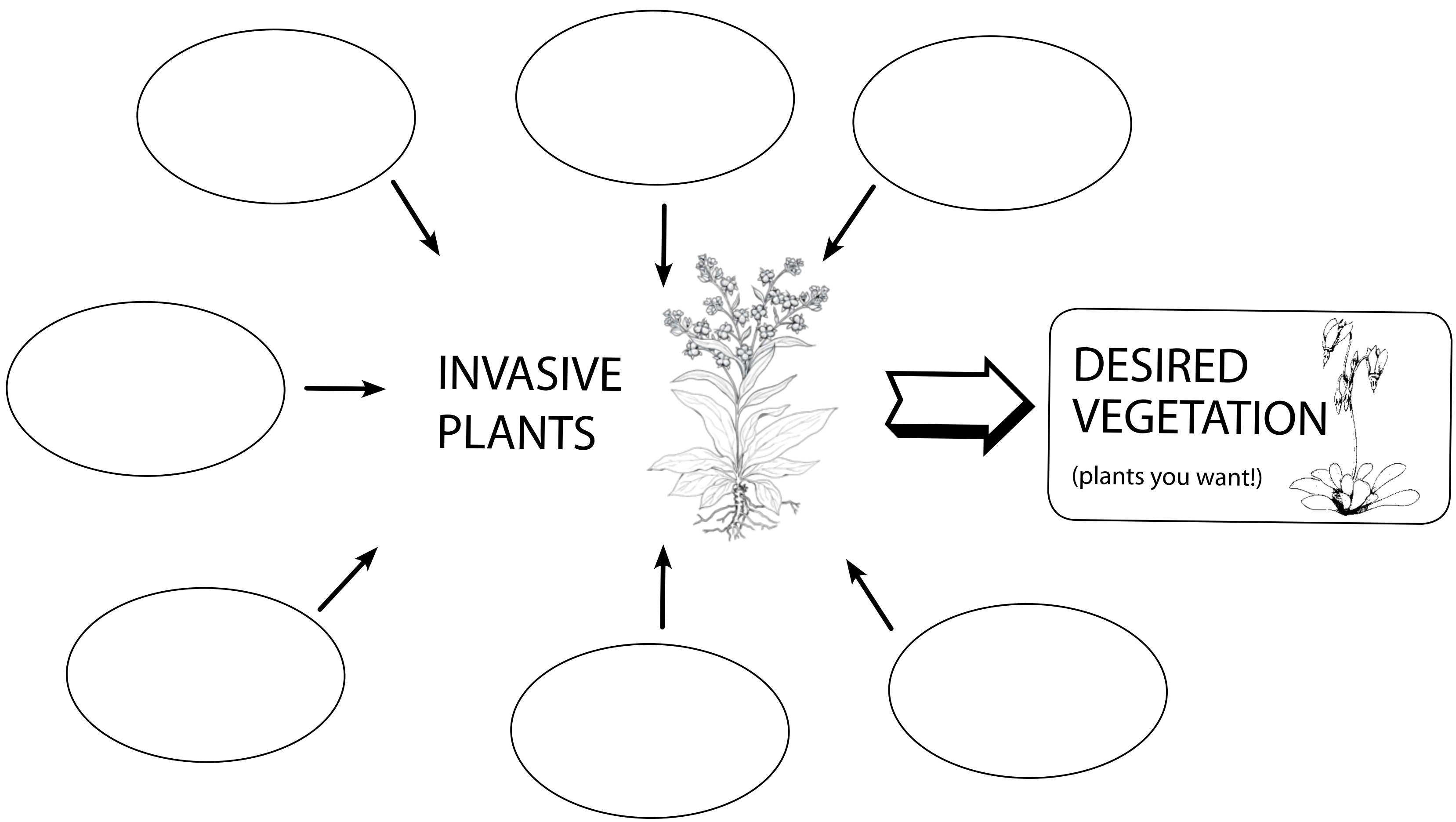
What kinds of things do you think might make it easier for non-native plants to invade an area and replace desired plants, such as native plants or agricultural plants? Can you think of human factors? Natural factors?



IPM Flowchart

2

What kinds of things might be done to decrease invasive weeds and help an area return to the desired vegetation?



IPM Flowchart

WORDS AND TERMS AS USED IN THIS GUIDE

Invasive Plant Glossary

Allelopathy – The ability of some plants to produce chemicals that inhibit the growth or germination of other plants nearby.

Annual – A plant that completes its life cycle in less than one year.

Biennial – A plant that requires two years to complete its life cycle. During the first year, it usually is a rosette of basal leaves, and during the second year it develops one or more flowering stalks.

Biological control / Biocontrol – The control of unwanted plants or animals by upsetting their ecological status through the use of organisms that are natural predators, parasites, or pathogens.

Biodiversity – The variety of different species or types of organisms in an area or, in global terms, on earth. For example, an area with 10 species would generally be considered to have more biodiversity than an area with 5 species.

Bulb – A short underground stem enlarged by modified leaves which contain no chlorophyll and are pressed together. Bulbs store nutrients and water for rapid spring growth. They are spheroid in shape, with short coarse roots below.

Chlorophyll – The pigment in green plants that absorbs solar energy.

Competition – A contest for resources in *limited supply*. Intraspecific competition occurs among members of the same species. Interspecific competition occurs among members of different species. Plants may compete for light, nutrients, water, or space.

Dichotomous key – A tool used to correctly identify species. Dichotomous means "divided into two parts". In a dichotomous key, the user is given a series of choices between 2 statements about characteristics of the organism. Each choice leads to another pair of statements until the name of the organism is reached.

Ethnobotany – The study of people's relationships to plants. Ethnobotany attempts to learn about how cultures perceive and use plants (e.g. for food, medicine, cosmetics, dyes, textiles, building materials, and in literature, rituals, and social life.)

Endemic – Populations of native animals, plants or other organisms, that are have relatively restricted distributions and are confined to certain environments.

Herbivory – The consumption of plants by animals.

Invasive Species – A non-native species that does or is likely to cause harm to the environment, economy, or human health where it was introduced. Invasive species display rapid growth and spread, allowing them to establish over large areas. Invasive plants reproduce rapidly, either vegetatively or by seed. Their rapid growth and freedom from natural enemies allows them to displace existing vegetation and often form dense one-species stands.

Inventory – A census which records all species or a subset of species, such as invasive plants, within an entire area.

Monitor – To sample repeatedly from plots within populations to detect changes in a resource (e.g., vegetation).

Native (indigenous) species – One that occurs in a particular region, ecosystem, and habitat without direct or indirect human actions. Species native to North America are generally recognized as those occurring on the continent prior to European settlement.

Noxious weed – A legal term used by the government to designate non-native plant species of particular concern and mandate their control. The Montana Noxious Weed Law states: "Noxious weeds" or "weeds" means any exotic plant species established or that may be introduced in the state that may render land unfit for agriculture, forestry, livestock, wildlife, or other beneficial uses or that may harm native plant communities and that is designated:

(i) as a statewide noxious weed by rule of the department; or

(ii) as a district noxious weed by a board, following public notice of intent and a public hearing.

Perennial – A plant that lives for several years, often producing flowers each year.

Photosynthesis – The process by which plant cells use solar energy to produce oxygen and chemical energy. In photosynthesis, the sun's energy combines hydrogen from water (H_20) with carbon dioxide (CO_2) turning them into carbohydrates. Oxygen (O_2) is given off as a by-product of photosynthesis. The chemical equation for the process of photosynthesis is: $6CO_2 + 6H_20 + \text{light} = C_6H_{12}O_6 + 6O_2$

Population – The number of a species living in an area.

Pubescent – Being covered with short soft hairs

Respiration – Plants (and animals) convert the sugars back into energy for growth and to energize life processes (metabolic processes). The chemical equation for respiration shows that the sugars from photosynthesis are combined with oxygen. The equation for respiration is the opposite of photosynthesis: $C_6H_{12}O_6 + 6O_2 = 6CO_2 + 6H_20 + \text{energy}$

Stoma (*plural*: stomata) – A tiny pore in a plant leaf surrounded by a pair of guard cells that control its opening and closing, and serves as the site for gas and water exchange.

Survey – A sample of a representative portion of an area, usually at points or along transects, to determine the presence, abundance, and/or distribution of plant species.

Taproot – The root system consists of a central taproot that originates from the base of the plant. This taproot can be slender or rather stout, and usually has fine rootlets towards the growing point.

Tuber – A starchy storage organ (such as a potato) formed by swelling of an underground stem or the end of a root.

Vegetative reproduction – A process by which new individual plants start not by seeds or spores, but instead grow from the non-reproductive parts of plants such as roots or stems.

Weed – A subjective word used to describe any plant considered to be "out of place", or growing where someone wishes it wasn't growing.

NATIVE PLANT AND WEED EDUCATION IN MONTANA

Resources

PLANT BIOLOGY AND IDENTIFICATION

Botany in a Day, Fifth Edition by T.J. Elpel. 2004. HOPS Press, Pony, MT.
www.hollowtop.com

Plants of the Lewis and Clark Expedition by H. Wayne Phillips. 2003.
Mountain Press Publishing Co., Missoula, MT

Plants of the Rocky Mountains by Kershaw, MacKinnon, and Pojar. 1998.
Lone Pine Publishing, Edmonton, AB.

Field guide to Montana plants is an online state field guide:
http://fieldguide.mt.gov/displayClasses.aspx?Kingdom=Plantae

Montana Plant Life has photos and information about native and non-native plants in Montana, including categories of edible and medicinal plants and weeds:
http://montana.plant-life.org

USDA national plant database with plant photos, identification, natural history, and distribution maps, including by Montana counties: http://plants.usda.gov

MONTANA NATIVE PLANT RESOURCES

The Magic of Montana Native Plants: A Gardener's Guide to Growing Over 150 Species from Seed. Morrison, S. 2002.
Montana Native Plant Press, Missoula, MT, USA

Blackfoot Native Plants is a family operated nursery in Montana's Potomac Valley bordering the Blackfoot River. They sell plants for use in perennial gardens, native meadows, and restoration settings in USDA Zones 2-3. The nursery specializes in native plants from Western Montana: http://blackfootnativeplants.com/

Montana Native Plant Society: http://www.mtnativeplants.org/

Windflower Native Plant Nursery specializes in raising Montana native plants that are indigenous to the Northern Rocky Mountain ecosystem:
http://www.windflowernativeplants.com/

ETHNOBOTANY / EDIBLE, MEDICINAL AND DYE PLANTS AND AGRICULTURE IN MONTANA

Bushcraft by Mors Kochanski. 2008. Lone Pine Press, Edmonton, AB.

Edible and Medicinal Plants of the Rockies by Linda Kershaw. 2000.
Lone Pine Publishing, Edmonton, AB.

From Earth to Herbalist by Greg Tilford. 1998.
Mountain Press Publishing, Missoula, MT.

Medicinal Plants of North America: A Flora Delaterre Coloring Book
by Beth Judy. 2007. Flora Delaterre Productions, Missoula, MT.
www.floradelaterre.com

Montana Native Plants and Early Peoples by Jeff Hart. 1976. Montana Historical Society Press, Helena, MT.

North American Dye Plants by Anne Bliss. 1993. Interweave Press. Loveland, CO.

Participating in Nature by Thomas J. Elpel. 1992. HOPS Press, Pony, MT. www.hollowtop.com

The Chemistry of Plant and Animal Dyes by Margareta Sequin-Frey. Dominican College of San Rafael, San Rafael. CA 94901

Ag in Montana Schools Curriculum Guide. A collection of lessons on Montana agriculture: http://www.aginmontanaschools.org/pdf/guideCrops.pdf

Amazing Grazing Lessons Plans and Activities for Grades K-12. Lessons on range science and grazing in Montana: http://www.animalrangeextension.montana.edu/amazgraze/index.htm

Glacier National Park curriculum for grades 4-6 on Native American uses of plants. Lessons on plant use by tribes in and around Glacier Park: http://www.nps.gov/glac/forteachers/4-6-unit-three-our-medicine-our-food.htm

Kootenai National Forest list of edible and medicinal plants: Information on traditional uses of plants of northwestern Montana: http://www.fs.fed.us/r1/kootenai/resources/plants/plants/edible_medicinal/list.shtml

Making Natural Dyes from Plants. Information on how to use plants to dye cloth: http://nyny.essortment.com/naturaldyeplan_rxll.htm

Montana Native Plant Society: Native Plants traveling trunks. This trunk is rich in materials, field guides, curriculum, and visual aids to identify plants native to the Rocky Mountain palouse prairie region. Grade level: 3-8: http://www.thenaturecenter.org/resources/trunks.htm

NativeTech: Native American Technology and Art. Information on traditional native uses of plants in North America: http://www.nativetech.org/plantgath/plantgaht.htm

National Agricultural Statistics Services Montana Overview. Data on many aspects of agriculture in Montana: www.nass.usda.gov/Statistics_by_State/Ag_Overview/AgOverview_MT.pdf

Natural Dyes from Plants. An interdisciplinary lesson plan for grades 4 and up on Native American use of plants for dye: http://www.museum.state.il.us/muslink/pdfs/dye_plants.pdf

The Plant Detective. Radio Show and Audio files on edible and medicinal plants from around the world: http://floradelaterre.com/

UBC Botanical Garden and Centre for Plant Research Weblog on Novel Uses of Plants. Information on unusual plant uses: http://www.ubcbotanicalgarden.org/weblog/cat_novel_uses_of_plants.php

T-Shirts to Dye For. Lesson plans for grades K-12 on dyeing t-shirts with natural plant dyes: http://www.education-world.com/a_lesson/02/lp259-04.shtml

INVASIVE PLANTS

Cornell Scientific Inquiry Series: Invasion Ecology (grades 9-12)
by Marianne Krasny. 2003. NSTA Press.

Invasive Plants of Western North America: An Introduction to Problematic Widespread Species by James Kavanagh. 2003.
Center for Invasive Plant Management and Waterford Press, Phoenix, AZ.

Invasive Plants: A Guide to Identification, Impacts, and Control of Common North American Species by Sylvan Ramsey Kaufman. 2007.
Stackpole Press, Mechanicsburg, PA.

Montana's Noxious Weeds by Monica Pokorny and Roger Sheley. 2001.
MSU Extension Service, Bozeman, MT.

The **Center for Invasive Plant Management** (CIPM) promotes ecologically sound management of invasive plants by facilitating collaboration and partnerships among scientists, educators, and land managers. It supports an online textbook, K-12 curriculum, identification and management resources, related links, and printed and other educational resources: **http://weedcenter.org**

Field Guide to Noxious and Other Selected Weeds of British Columbia provides identification and other information:
http://www.agf.gov.bc.ca/cropprot/weedguid/weedguid.htm

The **INVADERS Database System at the University of Montana** is a comprehensive database of exotic plant names and weed distribution records for five states in the northwestern United States. The spread of weeds can be displayed using the historic distribution records in INVADERS:
http://invader.dbs.umt.edu/

Invasive.org provides an accessible archive of high quality images related to invasive and exotic species, with particular emphasis on educational applications. WeedUS is a database of information about plants that invade natural areas in the U.S. It is intended as an informational and educational tool:
http://www.invasive.org/weeds.cfm

Invasive Species Educational Resources provides opportunity for interactive collaboration: **http://www.invasivespecies.org/resources/**

Invasive Species: Tamarisk's Use of Water. This computer animation illustrates the growth of root system of the invasive Tamarisk verses that of a native tree:
http://svs.gsfc.nasa.gov/goto?10096

Invasive weeds booklet for elementary students online. This is a story about invasive plants, why they are a problem, and what can be done about them in a picture-book format: **http://acwm.co.la.ca.us/PDF/invasive_weeds_book.pdf**

The **Missoula County Weed District** has information on weed i.d. and management, and educational links: **http://missoulaeduplace.org/weeds.shtml**

Montana's Statewide Noxious Weed Awareness and Education Campaign Website. This site has information for the general public, landowners, developers, and many other groups. There are also links for teachers and students:
www.weedawareness.org

Montana War on Weeds. This site is created, built and maintained by Whitehall High School students as an educational project, in cooperation with the Montana Noxious Weed Trust Fund, Montana Department of Agriculture, Whitehall Schools and Madison and Jefferson County Weed Districts: http://mtwow.org/

Montana Weed Control Association website. This site has information on weed identification and control, and links to other weed resources: www.mtweed.org

Natural Resources Conservation Service Noxious Weed Treatment Quick Reference poster available at http://www.weedawareness.org/weed_poster.pdf

US Forest Service *Color Noxious Weeds* are weeds you can color! Each coloring page includes a noxious weed drawing and facts about why the plant is considered a noxious weed: http://www.fs.fed.us/wildflowers/kids/coloring/colornoxiousweeds.shtml

Wildflowers and Weeds website from Pony, MT: http://www.wildflowers-and-weeds.com/index.html

Weeds Gone Wild: Alien Plant Invaders of Natural Areas provides information on the impacts of invasive plants to natural ecosystems of the United States. This site provides illustrated fact sheets that include plant descriptions, native range, distribution and habitat in the U.S., management options, suggested alternative native plants, and other information, and selected links to relevant people and organizations: http://www.nps.gov/plants/alien/index.htm

OUTDOOR LEARNING AND SCIENCE INQUIRY

Discovering the Naturalist Intelligence: Science in the Schoolyard by Jenna Glock, Susan Wertz, Maggie Meyer. 1998. Zephyr Press.

Schoolyard Science. Grades 2-4 by Peggy Purdue. 1991. Scott, Foresman and Company, East Lake, IL

The ***Butterfly Project Nature of Science*** site provides links and activities related to teaching about the nature of science: http://www.teacherlink.org/content/science/class_examples/Bflypages/nos.htm

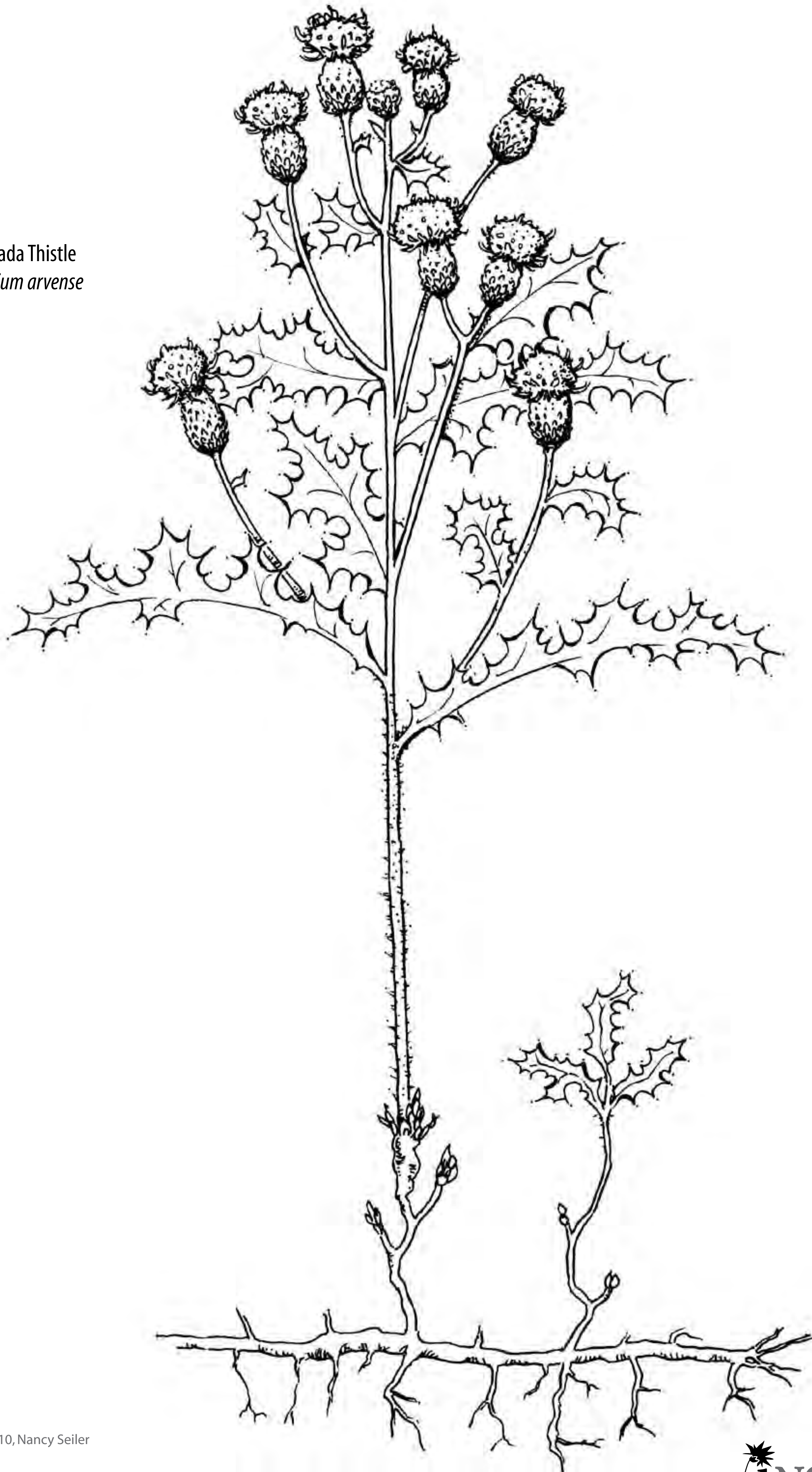
North American Association for Environmental Education. Links on this page are for activities and materials dealing with the school environment: http://eelink.net/pages/EE+Activities+-+Schoolyard+Ecology

Science for All Americans, the online resource of The American Association for the Advancement of Science, seeks to improve scientific literacy: http://www.project2061.org/publications/sfaa/online/sfaatoc.htm

Students in a Project-Based Learning Approach to Schoolyard Habitat Development. This website has online schoolyard experiments, links, and materials for teachers: http://web.stclair.k12.il.us/splashd/schlyrd.htm

US Fish and Wildlife Service's Managing Invasive Plants: Concepts, Principles and Practices provides information and definitions of inventory and survey techniques: http://www.fws.gov/invasives/staffTrainingModule/assessing/inventory.html#part1

Canada Thistle
Cirsium arvense

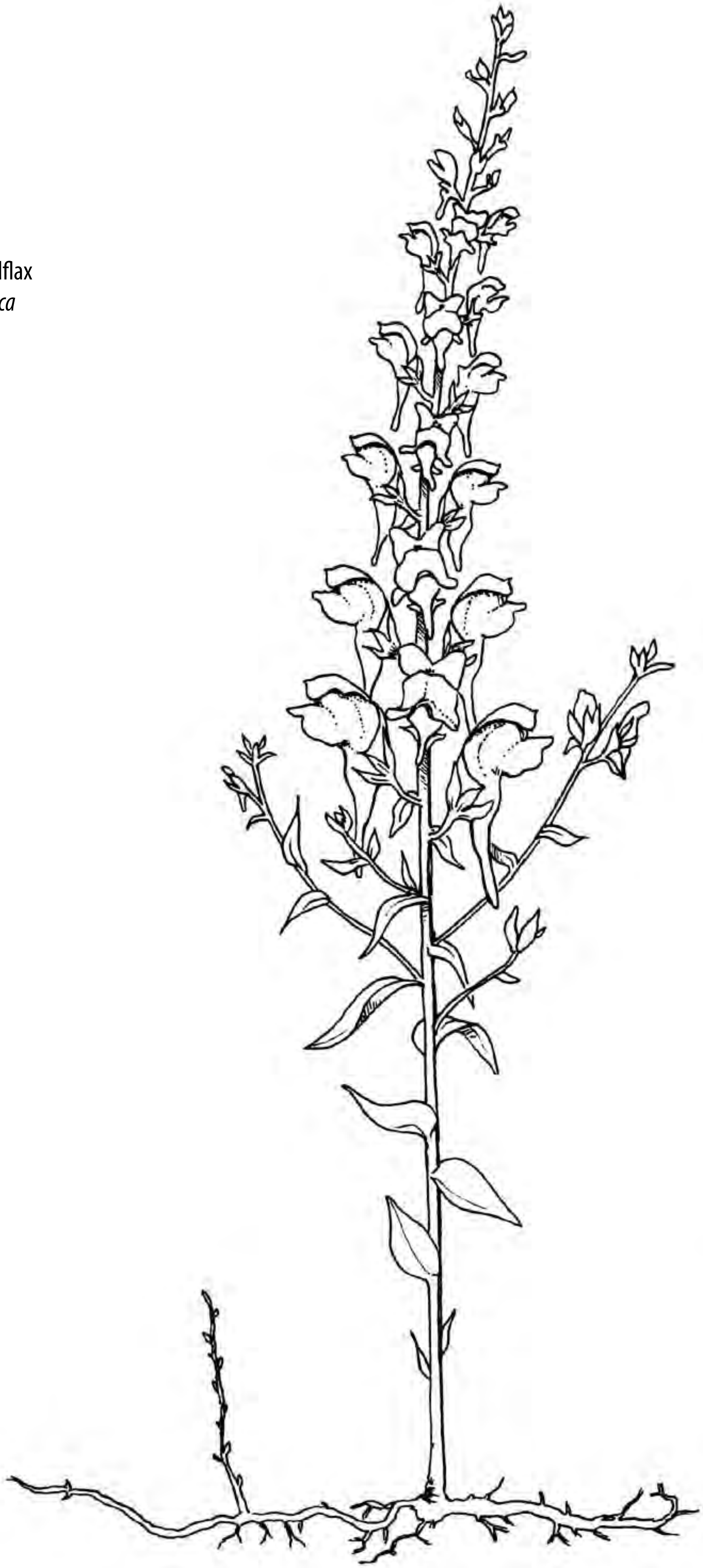


kNOweeds

Common Tansy
Tanacetum vulgare

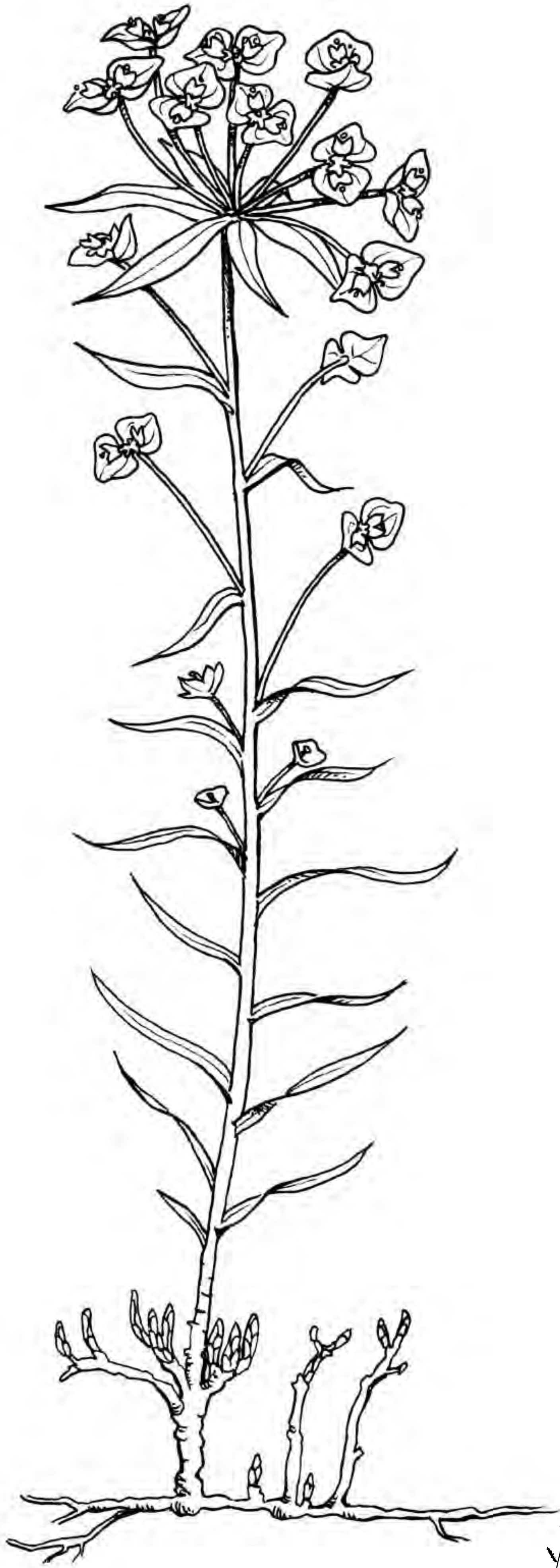
kNOweeds

Dalmatian Toadflax
Linaria dalmatica



kNOweeds

Leafy Spurge
Euphorbia esula

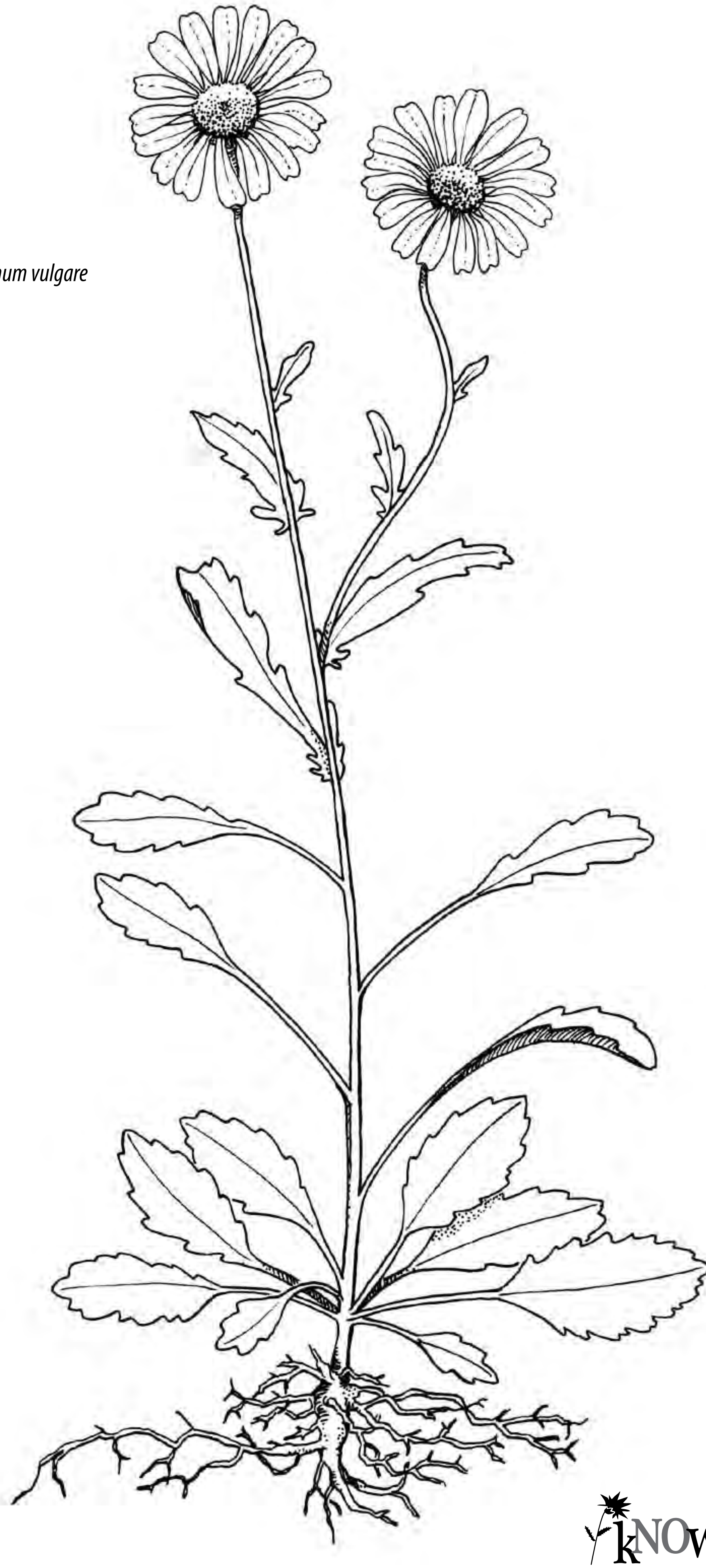


kNOweeds

Houndstongue
Cynoglossum officinale

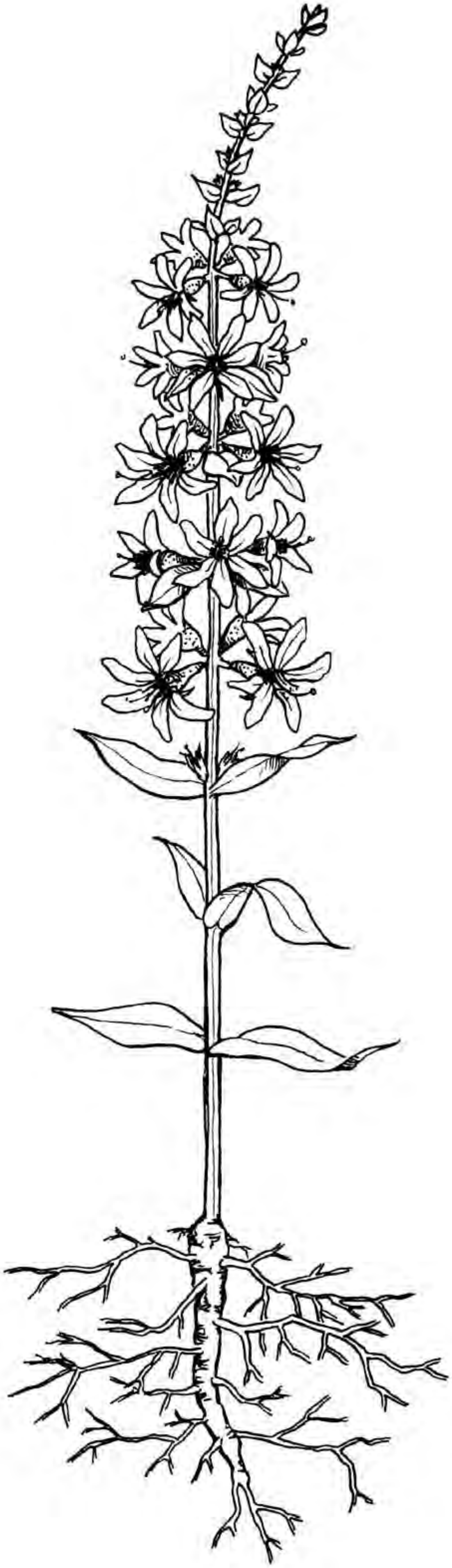
kNOweeds

Oxeye Daisy
Chrysanthemum leucanthemum vulgare



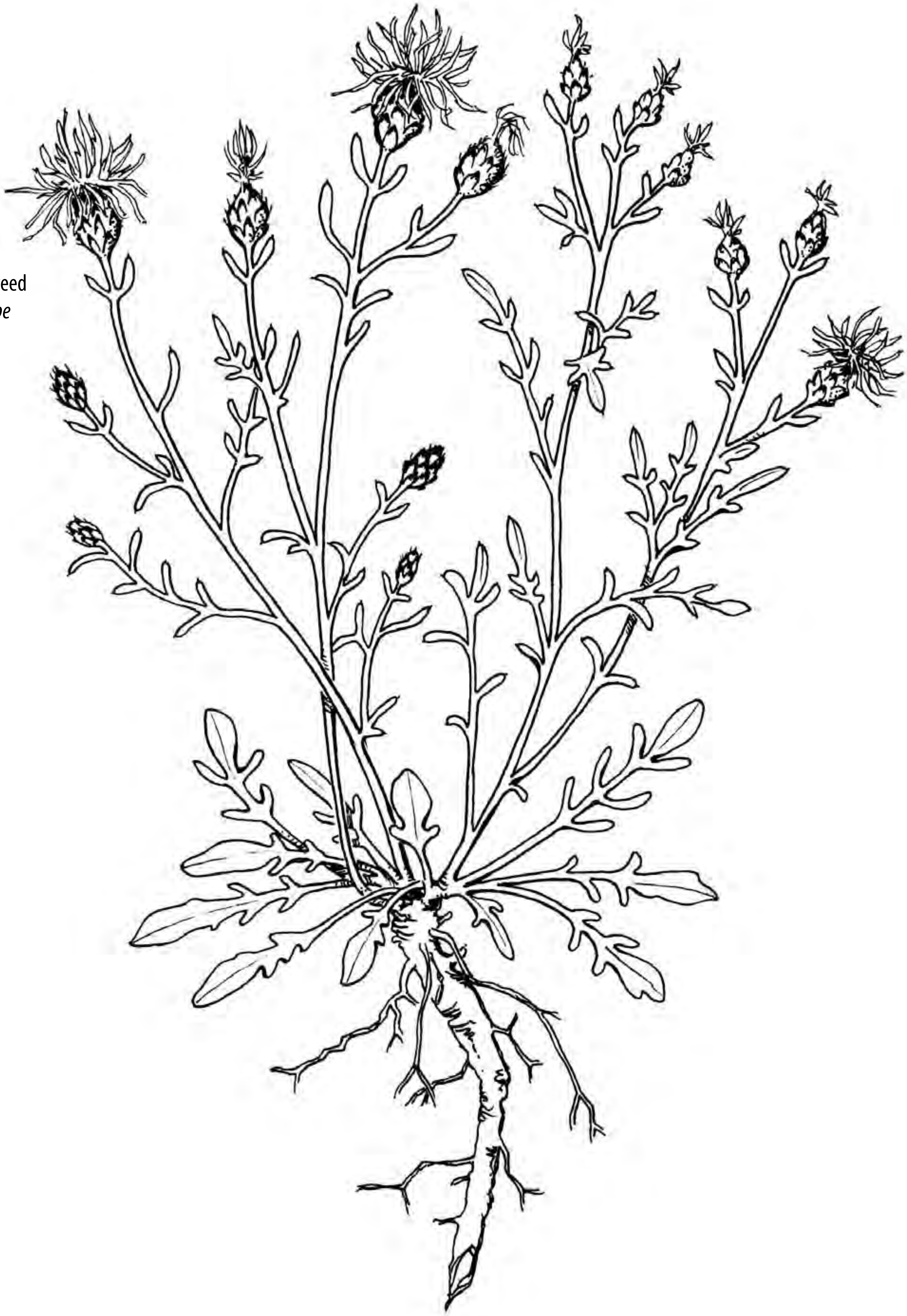
kNOweeds

Purple Loosestrife
Lythrum salicaria



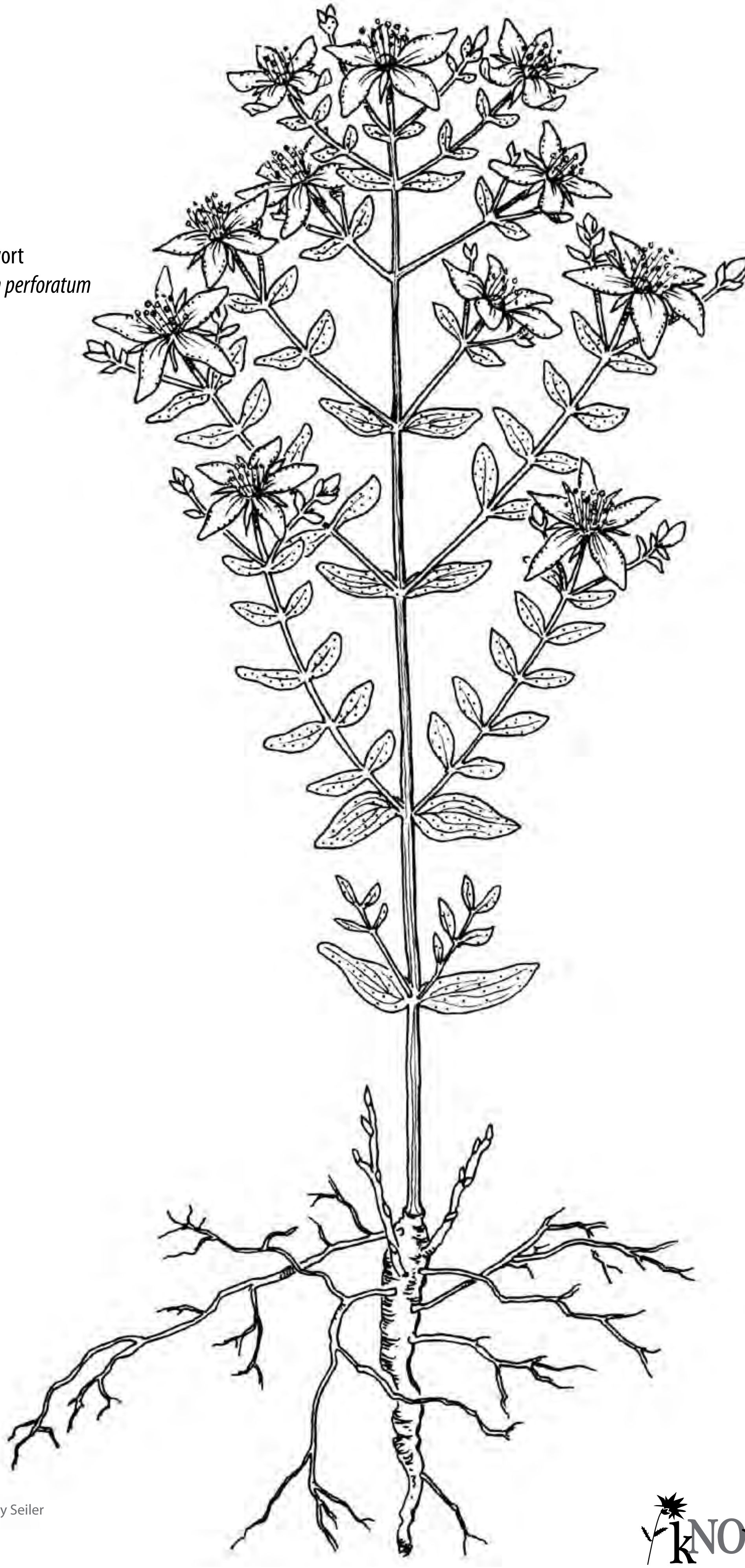
kNOweeds

Spotted Knapweed
Centaurea stoebe



kNOweeds

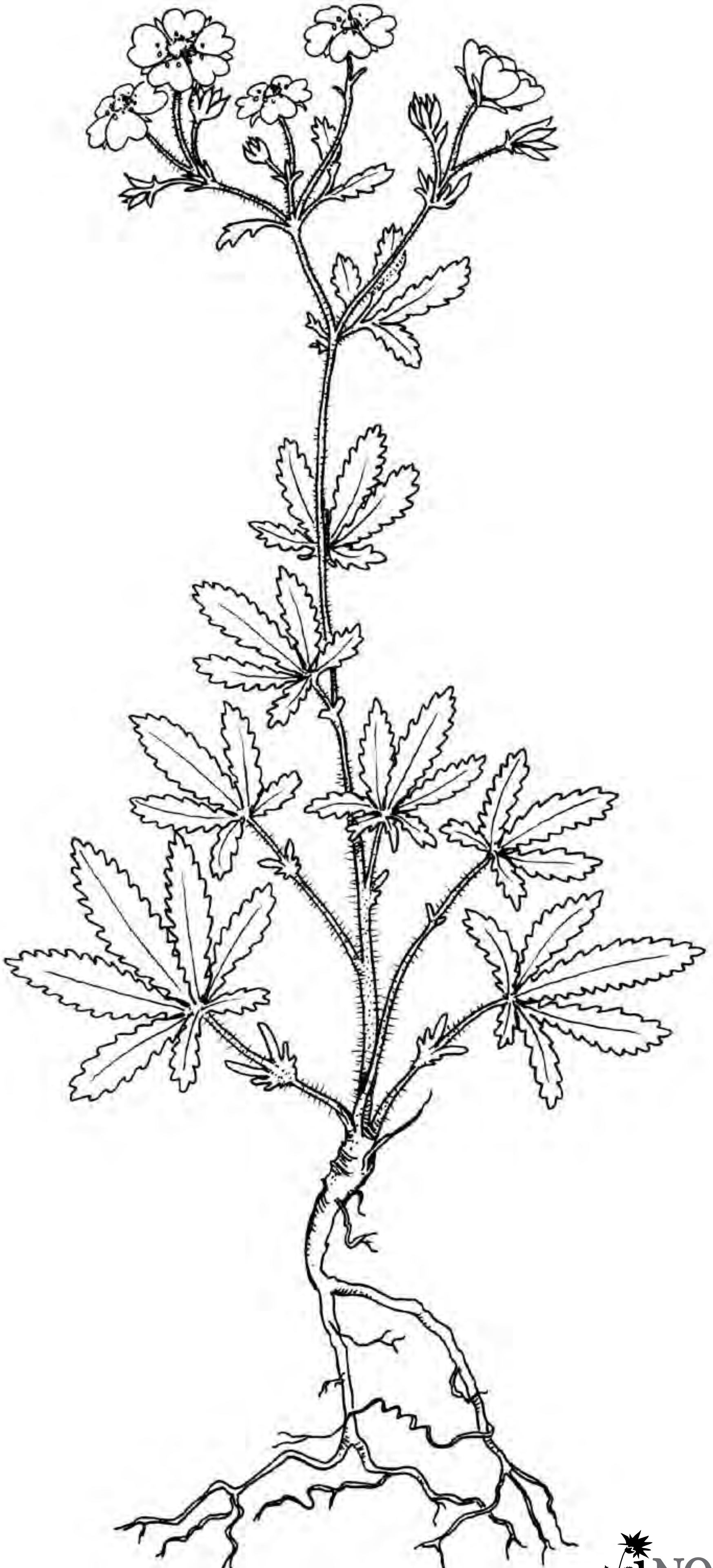
St. Johnswort
Hypericum perforatum



kNOweeds

kNOweeds Coloring Page

Sulphur Cinquefoil
Potentilla recta



Purple Loosestrife
Lythrum salicaria

Sulphur Cinquefoil
Potentilla recta

Leafy Spurge
Euphorbia esula

MISSOULA COUNTY
WEED DISTRICT

(406) 258-4211
www.missoulaeduplace.org