4-H 918

Biological Control of Purple Loosestrife

4-H Leader's Guide

Illinois-Indiana Sea Grant
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Note: The activities in this manual are intended for high school-aged students. Students in middle school should be able to do many of the exercises as well. With appropriate adult assistance, students of any age can learn from this activity book.

The Biological Control of Purple Loosestrife 4-H program joins students, youth leaders, educators, citizens, and scientists in the biological control of purple loosestrife using its natural insect enemies. This ecologically sound approach allows infested wetland habitat to return to a more natural state.

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NOTE: Most of the information and activities in this manual were adapted from the following publications:

- Klepinger, M., Chapman, D., Corlew, M., Dann, S., Francke, L., Haas, M., Heidemann, M., Hesselsweet, A., Landis, D., Parker, J., Potter, J., Sebolt, D., *The Purple Loosestrife Project Cooperator's Handbook*, Michigan State University.

- Jeffords, M.R.; Post, S.L.; Wiedenmann, R.N.; Voegtlin, D.J., *Biodiversity, Wetlands, and Biological Control: Information and Activities for Young Scientists. Purple Loosestrife: A Case Study*, Teacher Training manual (in progress). Collaborating entities: Illinois Natural History Survey, Chicago Wilderness, U.S. Fish & Wildlife Service, and the Illinois Department of Natural Resources.

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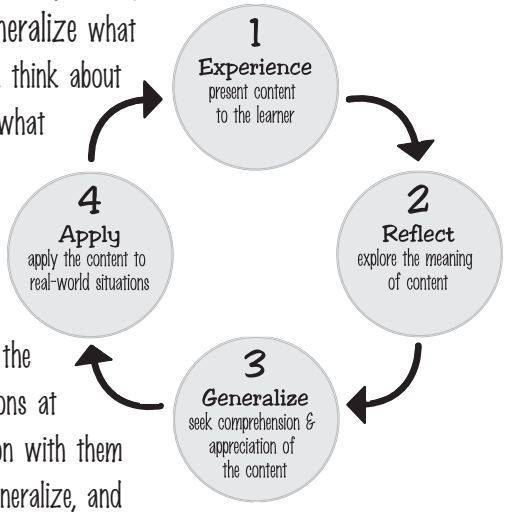
Experiential Learning

Experiential learning distinguishes 4-H youth development education from many formal educational methods. Activities are designed so youth experience a learning activity, reflect on what they did, generalize what they learned, and then think about how they can apply what they learned to other situations. You can help guide youth as they explore each activity by discussing the statements and questions at the end of each section with them (Experience, Reflect, Generalize, and Apply).



Objective

This guide was developed to help you help youth understand how to control purple loosestrife using a natural predator. It provides "learn-by-doing" activities that teach youth about biocontrol of purple loosestrife. Many of the questions in the manual are interpretive, that is, they have no "right" or "wrong" answer. Try to let your 4-H members explore possible answers and generate thought and discussion about these questions. Other questions may have a specific answer that the youth can't answer. You can supply these answers or encourage research so the youth can find the answers themselves. The techniques you choose will depend largely on how much time you have to work with the 4-H members and their level of interest.

This manual gives an introduction to the problems caused by purple loosestrife infestations of our wetlands, some principles and practice of biological control, and raising and introducing Galerucella beetles to control purple loosestrife in local wetlands. The student manual has activities that can be done in a group setting or individually. Feel free to use them (or not) in a manner that works best for the youth you teach. Answers to the questions in the youth activities are given in this leader's guide.

Learning Characteristics for Youth Ninth - Twelfth Grade

Most high school-aged teens know their abilities, interests, and talents. These teens tend to be very concerned with themselves and their peer group. Relationship skills are usually fairly well developed. Dating increases. Acceptance by members of the opposite sex is very important.

High school-aged youth begin to think about the future and make realistic plans. Their vocational goals influence the activities they select. Teens set goals based on their personal needs and priorities - goals set by others are generally rejected. As teens master abstract thinking, they may imagine and try new ideas in ways that confuse adults. Teens can generally initiate and complete tasks without supervision. A leader can help by arranging new experiences in areas of interest to teens but must be sure to allow them plenty of input. The leader should play the role of advisor/coach for independent workers.

Life Skills

Youth will develop the following life skills while working on this endeavor: making decisions, solving problems, relating to others, planning and organizing, communicating with others, leadership, relating to change, and applying science process skills.

Internet Sites for more information

- National Sea Grant Nonindigenous Species
  http://www.sgnis.org
- University of Illinois
  http://www.inhs.uiuc.edu/cbd/loosestrife/bcpl.html
- Michigan State University
  http://www.msue.msu.edu/seagrant/pp/
- Indiana Department of Natural Resources:
  www.state.in.us/dnr/entomolo/purple2.htm
- Cornell University:
  http://www.nysaes.cornell.edu/ent/biocontrol/weedfeeders/galerucella.html
- University of Guelph:
  www.uoguelph.ca/~obcp/
  www.uoguelph.ca/~obcp/factsheet/loosfa~1.htm

Overview

The Plant

Purple loosestrife is a native of Europe and Asia that has spread throughout much of the U.S. and Canada. Because the flower is so attractive, purple loosestrife has been sold as an ornamental plant. Recently, many states have banned its sale. Purple loosestrife grows an impressive four to seven feet tall. Its blooms are long spikes of showy purple flowers. It grows prolifically in wetlands and other moist areas. Each mature plant produces 30 or more flowering stems and can produce over 2.5 million seeds per year.

The Problem

A fierce competitor, purple loosestrife eventually overtakes native vegetation, forming nearly impenetrable stands of this single species. As the native plants are reduced, so too are the wildlife species that depend on them. Ecologists are concerned about the loss of native habitat for endangered plants and animals, and declines in ducks, muskrats, mink, and some amphibians. Dense stands of purple loosestrife also impair recreational use of wetlands and rivers and impede water flow in drainage ditches. Control by conventional means has proven to be extremely difficult, impractical, and ineffective on a large scale. Purple loosestrife infestations are a serious problem throughout the Great Lakes region and across North America.

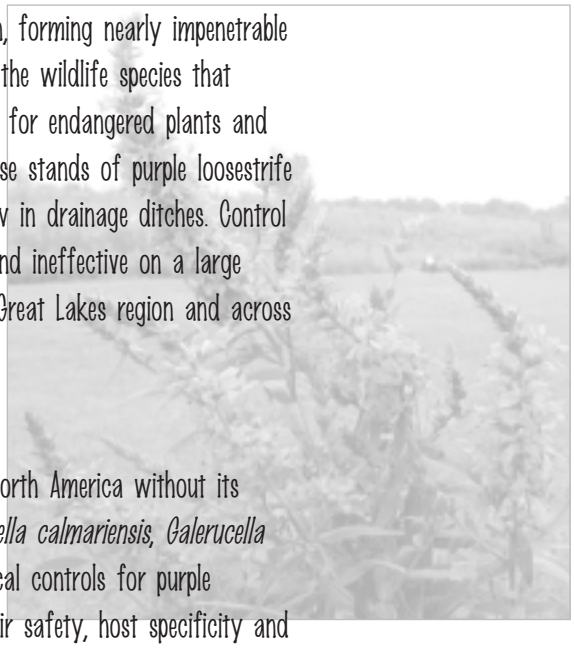


Photo: Pat Charlebois, Illinois-Indiana Sea Grant/Illinois Natural History Survey

A Solution

As often occurs with invasive exotic species, purple loosestrife arrived in North America without its natural enemies. Fortunately, three species of plant-feeding beetles, *Galerucella calmariensis*, *Galerucella pusilla*, and *Hylobius transversovittatus,* show particular promise as biological controls for purple loosestrife. These insects have undergone extensive testing to determine their safety, host specificity and effectiveness, receiving USDA approval for importation in 1992. *Galerucella* beetles feed on buds, leaves, and stem tissue, causing defoliation and prevention of flowering and seed production, eventually leading to plant death.

Will purple loosestrife disappear?

Those who enjoy purple loosestrife's colorful display need not fear. Experts agree that these natural enemies cannot eliminate purple loosestrife, only reduce its density and harmful effects. Biologists estimate that natural enemies may be capable of reducing the density of purple loosestrife by up to 90% over most of its current range. Remaining plants will serve to maintain a resident population of beetles for the future. Reducing purple loosestrife density will allow the re-establishment of native vegetation.

Citizen Involvement in the biological control of purple loosestrife

As part of the biological control effort, educators, students, and citizen leaders rear and release *Galerucella* beetles once they have received appropriate training. The teaching and learning opportunities are numerous, and inoculation of hundreds of infested wetlands is possible within just a few years.

Frequently Asked Questions

- What is purple loosestrife?
- Why should we want to control it?
- Isn't it good for anything?
- So how can we get rid of it?
- What are the control options?
- What is biological control?
- How effective is biological control?
- What natural enemies are approved for use?
- Where can I get the beetles?
- How long will it take for biological control to work?
- How safe is this approach?
- What will the beetles eat when purple loosestrife is gone?
- What can I do?

What is purple loosestrife?

Purple loosestrife (Lythrum salicaria) is a perennial plant native to Europe and Asia, which has become widely established in the U.S. and Canada. It grows and reproduces prolifically in wetlands and other moist habitats. Each mature 4 to 7-foot-tall plant produces 30 or more purple flower spikes that bloom in the summer and can produce over 2.5 million seeds per year.

Why should we want to control it?

For generations, wetlands were considered wastelands. Throughout the U.S., wetlands were drained until virtually none remained in some areas. It is now widely recognized that wetlands play important many roles. They provide habitats for native plants and wildlife, help to control flooding, enhance water quality, and are used for many types of recreation.

Purple loosestrife is degrading the quality of our precious remaining wetlands. Once it becomes established, purple loosestrife frequently becomes the dominant vegetation by outcompeting native plants. Wildlife species that depend on native plant communities are affected when the native plants decline. Declines in the number of wetland birds (ducks, geese, etc.), muskrats, mink, and some amphibians have all been noted. There is also concern that purple loosestrife may reduce spawning habitat for some fish.

Isn't it good for anything?

Purple loosestrife produces abundant nectar and is attractive to honeybees and other pollinators. Butterflies often obtain nectar from its blossoms. Redwing blackbirds use the stiff, erect stems as supports for nest construction. In the past, human beings greatly contributed to the spread of purple loosestrife, planting it for its beauty and reported medicinal qualities. Although it is beautiful, we now know better than to let it spread uncontrolled across the countryside.

So, how can we get rid of it?

For years, people have tried without success to eradicate purple loosestrife. It is now clear that eradication is impossible and we must find ways to live with this plant. Current efforts focus on two approaches to controlling, but not eradicating, purple loosestrife: (1) keeping it out of wetlands where it is not currently established and (2) where it is present, managing its density so that native plants and animals can prosper.

What are the control options?

There are several, and your choice depends on the particulars of the infested site. The best control strategy is dictated by the density and extent of infestation. See Appendix B for details.

What is biological control?

Biological control is when humans use a pest's natural enemies to reduce its density and the damage that it causes. Natural enemies may be predators, parasites, or pathogens.

Most people are familiar with the use of predators such as lady beetles to help control insect pests such as aphids on roses. Fewer are aware that biological control can also be used to help manage plants like purple loosestrife.

When purple loosestrife arrived in North America, it came without the natural enemies that attack it in its native home. Without these natural enemies, loosestrife populations can grow largely unchecked. Scientists know that in its native range, purple loosestrife is a part of wetland ecosystems, but never becomes the dominant vegetation. By careful study, they found several species of insects that feed on purple loosestrife, keeping its population in balance with other vegetation. The process of identifying, studying, and establishing these natural enemies where loosestrife has invaded is known as "importation biological control."

How effective is biological control?

Biological control has been practiced in the U.S. for over 100 years with both successes and failures. In this country, most of the effort has gone into the control of insect pests. Farmers in the Midwest are very familiar with the highly successful control of two exotic insect pests, the cereal leaf beetle and the alfalfa weevil, using parasites imported from Europe. The alfalfa weevil project is estimated to save U.S. agricultural producers $10 million per year in reduced pesticide usage and increased yields. Control of Klamath weed, another European invader of rangelands in the western U.S., was also highly successful in just a few years. However, in other cases natural enemies have failed to establish or never built up to sufficient numbers to impact the pest. Fortunately, in the case of purple loosestrife, some of these hurdles have already been overcome.

What natural enemies are approved for use against purple loosestrife?

Three species of plant-feeding beetles, *Galerucella calmariensis*, *Galerucella pusilla*, and *Hylobius transversovittatus*, show the greatest promise as biological controls for purple loosestrife. The *Galerucella* leaf beetles feed on bud, leaf, and stem tissue, causing defoliation and prevention of flowering/seed production. Continued defoliation can lead to plant death. *Hylobius* is a weevil whose larvae mine in root tissue, weakening and ultimately killing the plant. These insects have undergone extensive testing to determine their safety and effectiveness, receiving USDA approval in 1992.

Where can I get the beetles?

Because some states have restrictions on the importation of certain insects, 4-H Leaders need to work with their local Extension Educator to determine the proper way to obtain the biological control agents. Local Extension Educators should check with their State 4-H Office to see if this effort is being supported. State 4-H Departments should check with the State Entomologist at the Department of Natural Resources to find their preference and current policy regarding the importation of *Galerucella calmariensis*, *Galerucella pusilla,* or *Hylobius transversovittatus,* and to see if releases are under way and what documentation by 4-H Leaders will be required.

How long will it take for biological control to work?

Most estimates range from 5 to 15 years for large impacts of these beetles to be realized. However, recent results from Illinois, Minnesota, and Ontario indicate that *Galerucella* can have a dramatic impact on purple loosestrife infestations in as little as three years. Larger releases and better rearing techniques may help to shorten the time to impact.

How safe is this approach?

Before introduction of any weed biological control agent, it must pass several tests to determine its level of host specificity and to establish that it is free of unwanted diseases or parasites. The *Galerucella* and *Hylobius* beetles were initially tested against 47 plant species that are either closely related to purple loosestrife, occur in the same habitat, or are important economic species. Based on this testing, these species were considered to be host specific to purple loosestrife and approved for release by the USDA. An additional 45 plant species were tested after the beetles were imported to North America. *Galerucella* and *Hylobius* beetles are also harmless to human beings and pets.

What will the beetles eat when the purple loosestrife is gone?

First, purple loosestrife will never be gone—biological control does not eradicate a species. There will always be some loosestrife for the beetles to eat. Because normal feeding and growth occurs exclusively on purple loosestrife, the number of the beetles in any area rises and falls in relation to the amount of loosestrife present. As the plant becomes less common, the beetles will have a harder time finding food, they will produce fewer offspring, and as a consequence, their population will decline. Once established, the beetles will continue to control loosestrife on a permanent basis.

Meeting the Standards

4-H Skill Areas addressed by working with biological control of purple loosestrife

- Critical Thinking
- Problem Solving and Decision Making
- Working with Groups
- Acquire, Analyze, and Use Information

4-H Program Areas addressed by working with biological control of purple loosestrife

- Citizenship and Civic Education
- Environment
- Plants and Animals
- Science and Technology

National Science Education Standards addressed by working with biological control of purple loosestrife

- Science as Inquiry
- Abilities Necessary to do Scientific Inquiry
- Understandings about Scientific Inquiry
- Life Science
- Interdependence of Organisms
- Populations and Ecosystems
- Diversity and Adaptations of Organisms
- Reproduction and Heredity
- Science in Personal and Social Perspective
- Population Growth
- Natural Resources
- Environmental Quality
- Natural and Human-induced Hazards
- Science and Technology in Local, National, and Global Challenges
- Risks and Benefits
- History and Nature of Science
- Science as a Human Endeavor
- Historical Perspectives

Finding a Wetland

Biological control of purple loosestrife must take place at a wetland site infested with purple loosestrife. Work with appropriate personnel to identify an appropriate wetland site and obtain permission to use that wetland for your study.

Identifying an Appropriate Wetland Site

Who can help?

Most states are trying to keep close watch on the spread of purple loosestrife and efforts to control it. Work with your local Cooperative Extension office to find out what efforts are ongoing in your location and where help is especially needed. Local Extension Educators should check with their State 4-H Office to see if this effort is being supported. State 4-H Offices can check with the State Entomologist at state natural resources agencies or, in Illinois, the Natural History Survey, to find if releases are being made in your state and what documentation by 4-H Leaders will be required.

Site selection guidelines

Local authorities (natural resource agencies) can generally help you find sites for beetle release. Be sure you have spoken with them before you begin to raise the *Galerucella* beetles to be sure there is a place to release them in your area. Appendix H: Site Selection Guidelines will give you an idea of the things that must be considered in selecting an appropriate site for beetle release.

Obtaining Permission to Conduct Your Investigations at the Wetland Site

The local authorities that helped you find a wetland to release beetles in can also help you obtain the necessary permissions for the release. Procedures will vary depending on state regulations and who owns the property.

Timeline for Student Activities

	Activity	Time	Apr.	May	June	July	Aug.
1	Introduction to Wetlands	any time	x	xxxx	xxxx	x	
2	Aliens Among Us	any time	xxxx	xxxx	xxxx	xxxx	xxxx
3	Annual Wetland Plant Diversity Survey	May - June		xxxx	xxxx		
4	Is Purple Loosestrife a Problem in Our Country?	July - mid Aug.				xxxx	xxxx
5	Controlling Purple Loosestrife	any time	xxxx	xxxx	xxxx	xxxx	xxxx
6	Biological Control of Purple Loosestrife	any time	xxxx	xxxx	xxxx	xxxx	xxxx
7	Biological Control Agent: Host - Plant Specificity	any time	xxxx	xxxx	xxxx	xxxx	xxxx
8	Purple Loosestrife & *Galerucella* Beetle Rearing - pot plants -add beetles -new beetles emerge	 late Apr. early June early Aug.	xx	xxxx	xxxx	xx	
9	Observation & Life Cycles	any time	xxxx	xxxx	xxxx	xxxx	xxxx
10	*Galerucella* Beetle Release	late June - early Aug.			xxxx	x	xx
11	Evaluating the Impact of *Galerucella* on Purple Loosestrife (subsequent years) - beetles feeding on meristem - monitor for reduces flowering	 May - June July - Aug.		xxxx	xxxx	xxxx	xxxx

Activity One
Introduction to Wetlands

Leader Summary Sheet

General Description

This lesson is designed to help students begin to understand the value of wetlands. They will share their prior knowledge of wetlands, gain first-hand knowledge by visiting a wetland, and then develop a more advanced understanding of wetlands and their functions.

Season

Spring/Summer/Fall

Estimated Time

1-2 hours (depending on how long you visit the wetland and the travel time)

Materials

The first page of "Frequently Asked Questions" discusses the value of wetlands. You may also want to obtain a field guide for plant identification, available from libraries, county Extension offices, and university media distribution centers.

Reflect - Do you think that remaining wetlands should be protected?

Generalize - What are some benefits and disadvantages to protecting wildlands, wetlands, and other natural resources?

Apply - How can you help to protect wetlands and other natural resources?

Additional Information

You may need to have written permission to use the wetland before taking a field trip there.

The visit to the wetland has two main purposes. One is to give the students first-hand knowledge of wetlands as they try to understand their parameters and functions. The other is to get the students familiar with the particular wetland they will be investigating. Future activities that occur at the wetland will be more technical. Students will be able to focus on the technical activities if they are already comfortable in the wetland environment.

activity 1

Introduction to Wetlands

Objectives

- Didcuss wetlands
- Learn about the value of wetlands
- Learn about local wetlands.

Describe a wetland.

Students should take about 5 minutes to record their understanding of the term "wetland." This is an interpretive question – there is no "right" answer to this question. Students' answers are based on their prior knowledge of wetlands. Some students will have studied wetlands in great detail in school. Other students will not have extensive background knowledge of wetlands. You may want students to share their ideas. Remember, no answer is wrong.

Visit a wetland in your county. What does it look like? What does it sound like? What animals and plants do you find? Record your observations. Include some sketches.

Students will enhance their understanding of wetlands through personal experience in a wetland area. You may want to have field guides available to help students identify wetland plants and animals.

Discuss your observations with the group. What characteristics do you think distinguish wetlands from other habitats?

Through discussion, students begin forming a "definition" of a wetland. You may want to have one person record all of the responses on a large sheet of paper.

Scientists and resource managers define wetlands in many ways. Generally, all the definitions include three common characteristics of wetlands. What are these three major characteristics? *(Provide this information to your students. Did they have these components in their descriptions of a wetland?)*

1.) *Hydrology (water is present at some time)*

2.) *Hydrophytic Plants (plants that can grow in saturated soil conditions and/or drought conditions)*

3.) *Hydric Soils (special soils that have a high amount of organic matter content)*

Why are wetlands important?

1.) *Populations of animals depend on wetlands for survival.*

a) Animals harvested for pelts (fur-bearing mammals, alligators)

b) Waterfowl and other birds (shelter, food, hunting industry)

c) Fish and shellfish (spawning, recreational/commercial fishing)

d) Timber/peat harvest

e) Endangered and threatened species (Just 3.5% of U.S. land is in wetlands, yet 50% of endangered species depend on wetlands.)

2.) *The entire wetland ecosystem helps in many ways. They*

f) Decrease the danger of flooding and erosion

g) Absorb coastal storms (may want to discuss the impact of hurricanes on the East Coast—conservation of wetlands vs. coastal development)

h) Recharge groundwater

i) Improve water quality (remove toxic materials, act as filters that allow materials to settle, have lots of bacteria that remove chemicals)

j) Provide aesthetics (natural teaching labs, cultural heritage, beauty, etc.)

k) Supply subsistence for some cultures (wetlands as base for food sources—Alaska, Canada, Russia)

What percentage of natural wetlands have you lost in your area? How were they lost? A DNR (Department of Natural Resources) employee or your county Extension Educator may be able to help you with this.

Students should research this by themselves (take-home activity). They might look at photos of the area both pre- and post-settlement. They should use the Internet, reference books, wetland resources experts, etc. to determine the data for the state, region, county, or neighborhood.

Notes:

Activity Two
Aliens Among Us

Leader Summary Sheet

General Description

Each organism in an ecosystem survives in relationship to other organisms (biotics) and the physical nonliving environment (abiotics). In this activity students will investigate a wetland plant species, consider limiting factors to population growth, learn about native and non-native invasive plants, and begin to learn about purple loosestrife. Some questions that can be investigated are: how does introduction of a non-native species affect the dynamic balance of native ecosystems, what factors favor population growth of a species, and what biotic and abiotic factors influence species survival?

Season

Spring/Summer/Fall

Estimated Time

1-2 hours

Materials

- Field guides (optional), available from library, county Extension office
- Plant and animal reference books
- Pictures of wetland plants (unless you visit a wetland and use the field guides)
- Frequently Asked Questions (in this manual)

Reflect - Why do exotic species sometimes out-compete native species?

Generalize - How can competition for resources cause conflicts between species? Who should decide which species should be protected and what should this decision be based on?

Apply - How can citizens in your community be involved in these decisions?

Additional Information

It is best to take your 4-Hers to a wetland to select a plant species to study. This will allow the youth to become more familiar with the wetland and to have a more hands-on learning experience. The students will also have the opportunity to practice their observation skills. They can use their observations to determine the biotic and abiotic factors that influence their specific plant.

If it is not possible to go to a wetland site, you will need to provide the students with pictures of wetland plants. Another option would be for the students to bring information on a wetland plant to the group meeting.

You can use the following example to help students understand how to fill out their charts.

Example: Quackgrass (yard plant)

Biotic Potential	*Environmental Resistance*
Reproduction: grows by runners and seeds	*Competitors: dandelions, crabgrass, etc.*
Growth: rapid	*Water: tolerant of wide variation*
Migration: humans spread it	*Predators: few visible signs of predation; mowed by people.*
Coping: hardy, thrives in most soils	*Disease: few signs of disease*

activity 2

Aliens Among Us

Objectives

- Determine the likelihood that an exotic species will survive in a new area.
- Clarify the factors that might limit the survival and population growth of an exotic species.
- Learn about purple loosestrife's limiting factors.

Focus Questions

Each organism in an ecosystem survives in relationship to other living organisms (biotic factors) in the ecosystem. The physical non-living environment also affects each organism (abiotic factors). A healthy ecosystem has a dynamic (changing) balance between biotic factors for survival, abiotic factors, and environmental resistance to population growth of the species.

1.) Think of an organism in your area. List some factors that could increase the organism's chances of survival.
Reproductive rate, growth rate, ability to migrate and invade new habitats, defense mechanisms, ability to cope with adverse conditions

2.) List some factors that affects each organism (environmental resistance).
Insufficient water or nutrients, unsuitable habitat; adverse weather conditions; predators; disease; competition for resources

Examining a Wetland Plant

Choose a plant to study. List the factors that might influence its chances of survival (biotic factors) and limiting factors (environmental resistance) for the plant.

Wetland Plant: *example: cattail*

Factors Favoring the Plant	Factors Limiting the Plant
• high reproductive rate • aggressive competitor • able to migrate through seed spread	• lack of water • competition from other species

Exotic Species

Exotic species are plants or animals that are not native to an ecosystem. Exotic species that are able to out-compete native species are called invasive. Some native species are also invasive. See if you can complete the chart below by indicating if the plant listed is native to the U.S. or exotic, invasive or non-invasive.

Plant	Native	Exotic	Invasive	Non-invasive
Black locust	x		x	
Honeysuckle		x	x	
Japanese maple		x		x
Lilac		x		x
Multiflora rose		x	x	
Osage orange	x		x	
Sugar maple	x		x	
Thistle		x	x	
Tulip		x		x
Vetch		x	x	

Interaction Between Native & Exotic Species

Invasive plant species can interfere with the dynamic balance in an ecosystem.

1.) Based on its biotic potential and environmental resistance, how could an exotic plant get into a local wetland ecosystem?

Answers will vary. Possibilities include: floating, carried by animal, wind, and boats (ballast waters are often responsible for introduced exotic species in the Great Lakes). You may have the opportunity to discuss how the transfer of plants, animals, and diseases connects the world as people move between countries more freely.

2.) How do you think invasive plant species affect the other plants?

Answers will vary. Discuss the interactions between species - population growth, natural adaptations, etc.

3.) Based on its biotic potential and environmental resistance, how could people control the spread of your exotic plant?

Answers will vary. This question gets students thinking about solutions to the purple loosestrife problem. You may want to refer back to this question as a lead-in to Activity 5: Controlling Purple Loosestrife.

Introducing Purple Loosestrife

Purple loosestrife is an exotic plant species that affects many wetland ecosystems. Read about purple loosestrife and list the biotic factors influencing its chances of survival and environmental resistance to the plant.

You might suggest that youth visit the Internet sites listed in the front pages of this manual or make copies of the first page of the "Frequently Asked Questions" section for them to read.

Factors Favoring Purple Loosestrife	Factors Limiting Purple Loosestrife
· out-competes native plants · high seed production rates · ability to migrate to new habitats · can tolerate freezing temperatures · few, or no, native enemies	· drought · animal predators (possibly deer) · competition with cattails

Notes:

Activity Three
Wetland Plant Diversity Survey

Leader Summary Sheet

General Description

Students will learn to calculate a Diversity Index by working through their Activity Three worksheet at a wetland. You can teach them the concepts involved by following the example activity under "Preparation" before you visit the wetland. The diversity index value will be used to provide baseline information about the wetland area where you will release the beetles.

When working towards biological control of any species it is very important to evaluate the effect of your efforts. Changes in plant community diversity during and after a control project are used to evaluate the control method. Several questions will be studied in this activity:

- How do scientists measure diversity in plant communities?
- Is biodiversity increased after control measures are implemented?
- What is a Diversity Index, and how does it change over time?
- What changes in habitat result from control measures?

Students will randomly locate and establish a transect (line along which plants will be counted) in a purple loosestrife-infested wetland. They will count and identify the plant stems along the transect and calculate the Diversity Index.

A Diversity Index is a measure of how many individuals of a specific species occur in relation to all the species in the wetland. This index gives more detail than a percentage of one species because it gives an indication of the diversity of the wetland plants. For example, assume that 50% of wetland plants are purple loosestrife and the remaining 50% are one other species (e.g. cattail). This is a very different situation than a wetland with 50% loosestrife and the remaining 50% being 10 other species. Percentages would indicate that 50% of the wetland contains purple loosestrife in either case but actually the two scenarios are very different. The Diversity Index is a number that gives an indication of the diversity in the second example. A higher value for the Diversity Index is best. An increase in the diversity index shows your success in increasing plant diversity in the wetland as the years go by.

Season

May-June

Estimated Time

2 hours

Materials

- Six 10-foot long PVC pipes to use as stakes
- Three sections of stout cord, about 70 feet long (each)
- Clipboards & Calculator
- Field guides (available from library, cooperative extension office, etc.)

NOTE: The "Preparation" exercise (pg. 23) should be studied beofre traveling to the wetland.

Reflect - Why is it important to measure plant diversity?

Generalize - How does diversity help stabilize a population?

Apply - How can you help promote diversity in natue?

Preparation

1.) 4-Her can learn the concept of determining plant diversity before traveling to the wetland by using a box of animal crackers, a small bag with different types of beans, etc. Have the students pull out a cracker (or bean, etc.) without looking and record what they have [zebra(Z), elephant(E), tiger(T), bear(B), coyote(C), etc.] by designating the first letter. Examples:

Example 1: C C Z T E C Z Z Z B
Example 2: E E E E T T C C C C

2.) Count the number of "runs" (changes in animal type). The first example has 7 runs (7 changes) and the second example has 3 runs.

3.) Calculate the Diversity Index, DI_D, for each experiment, by dividing the number of runs by the total number of animal crackers withdrawn:

$$DI_D = \#\ \text{runs}/\#\ \text{crackers}$$

Example 1: $DI_D = 7/10 = 0.7$ Example 2: $DI_D = 3/10 = 0.3$

The value 0.7 shows greater plant diversity in example 1 than example 2 (0.3). Values closer to 1 are better. It does not tell us, however, if the plants are native plants. We can extend our calculations to get this information.

4.) Extending these calculations (optional): you can calculate other diversity indices, depending upon your focus. The calculations, and values calculated using the examples, are given below:

The basic Diversity Index, DI_D, was shown above and is calculated as

$$DI_D = \frac{\text{total \# of runs}}{\text{total \# of crackers}}$$

The Modified Diversity Index, DI_M, compares the diversity index of native plants to the total plant population and is calculated as

$$DI_M = \frac{\text{total \# of runs of native species}}{\text{total \# of runs}}$$

In our example and assuming that the bear and coyote are native (U.S.) species the DI_M would be:

example 1
$DI_M = 3/7 = 0.43$

example 2
$DI_M = 0.33$

The Species Diversity Index, DI_S, gives the diversity index for different species and is calculated as

$$DI_S = \frac{\text{total \# of different species}}{\text{total \# of runs}}$$

example 1
$DI_S = 5/10 = 0.5$

example 2
$DI_S = 3/10 = 0.3$

The Diversity Index of Exotic species, DI_E, is calculated by taking the square root of the basic Diversity Index times the Modified Diversity Index:

$$DI_E = \sqrt{(DI_0 * DI_M)}$$

example 1
$DI_E = \sqrt{(0.7*0.43)} = 0.55$

example 2
$DI_E = \sqrt{(0.3*0.33)} = 0.31$

The Overall Diversity Index, DI_0, gives a more precise measure of site diversity. It is calculated by taking the cubic root of the basic Diversity Index times the Modified Diversity Index times the Species Diversity Index (or the Diversity Index of Exotic species, if that is your chosen focus):

$DI_0 = \sqrt[3]{(DI_0, * DI_M * DI_S)}$ or $DI_0 = \sqrt[3]{(DI_0, * DI_M * DI_E,)}$

example 1
$DI_0 = \sqrt[3]{(0.7*0.43*0.5)} = 0.53$

example 2
$DI_0 = \sqrt[3]{(0.3*0.33*0.3)} = 0.31$

Note that there is a greater plant diversity in Example 1 than in Example 2, as was shown by the basic Diversity Index, but the values are lower because the effects of the proportion of native plants and total plants have been included.

If your 4-Her choose to calculate the Overall Diversity Index they should perform the calculations for each of three transects separately and average the three indices.

Notes

activity 3

Annual Wetland Plant Diversity Survey

Objectives

- Learn how to calculate the species diversity of a plant community.
- Determine if the density of purple loosestrife affects the diversity of the plant community.

Focus Questions

1.) What is diversity?

Being different, having differences, etc.

2.) Why is biological diversity important?

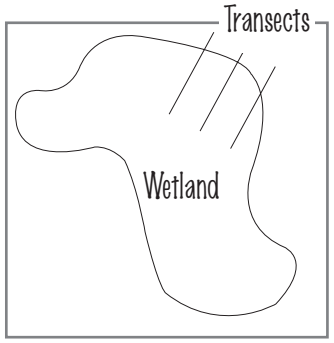
Biological diversity refers to the different species of organisms that inhabit the earth. It is important because all the organisms rely on each other. If we lose biological diversity, we will disrupt the earth's food web.

3.) How does plant species diversity affect a wetland?

Increased plant diversity in a wetland provides a variety of food and shelter for organisms, which generally results in an increased diversity of organisms.

Procedure for Calculating the Diversity Index

1.) Locate the edge of a wetland by noting where the vegetation changes to wetland plants. Establish three 70-foot-long transects (see the marked lines in the drawing) that run from the edge of the wetland into the interior (see the figure at the right). The transects should be parallel to each other and stop before hitting open water. Avoid trampling the plants that will be on your transect. Transects should be at least 32 feet apart. Pound in two PVC pipes as stakes to designate the ends of each transect and tie a stout cord between them. The poles will be left in place so you can easily calculate the Diversity Index in the future by comparing the same place each time.



2.) Walk along a transect with another 4-Her and identify each plant that touches the line (or is in the plane of the transect). Indentify genral plant categories rather than each individual plant, use the following categories: loosestrife (L), grass or sedge (G), cattail (C), and other (O, which would include broadleaf plants and vines). Your data sheet should be made of these letters to indicate the order you found them. For example, LLGLCLL would indicate that you saw two loosestrife plants, a grass, a loosestrife plant, a cattail, and two loosestrife plants.

3.) Determine the number of 'runs' (changes in species type) on your data sheet. Note that the example given in #2 has 5 runs (loosestrife, grass, loosestrife, cattail, loosestrife).

4.) Calculate the General Diversity Index (DI_g) by using the following equation:

$$DI_G = \frac{\text{total \# of runs}}{\text{total \# of plants}}$$

The value of DI_G will vary between 0 (no diversity) and 1 (high diversity). Values around 0.5 indicate that the wetland is relatively diverse. (Note: DI_G cannot equal 0 because there will be at least one run.)

Note: Keep records of the plant diversity, DI_G, for your wetland. Increasing the plant diversity is the goal of the Biological Control of Purple Loosestrife 4-H initiative. By increasing plant diversity in your wetland you are allowing native plants to reestablish themselves.

Follow-up discussion

Wetland resource managers say purple loosestrife is a problem because it tends to crowd out other wetland plants and to reduce the diversity of the wetland area. Based on the data your group collected, do you agree or disagree with the wetland resource managers? Defend your answer.
Answers will vary. Student should defend their answer based on the data they collected.

- Is this wetland healthy? Defend your answer.
  Answers will vary. Generally, the higher the species diversity, the healthier the wetland is. However, other factors (such as pollution) may affect their assessment of the health of the wetland.

- What could you do to improve the health of the wetland?
  Answers will vary. Some students might develop the idea of removing purple loosestrife from the wetland. If purple loosestrife decreases species diversity, removing it should increase the diversity and health of the wetland. This question also leads into the discussion of Controlling Purple Loosestrife (Activity 5).

Other Questions to Consider

1.) What other factors might affect the diversity of a wetland area? How could you test for or measure those?
Suggested answers: water quality, climate, animal life, wetness of area, and size of the wetland, pollution.

2.) Why did we only survey a small area within the wetland? Why didn't you count all the plants in the wetland?
Easier (especially time), could make projections for entire wetland, statistical sampling.

3.) You learned how to calculate plant species diversity. Do you think it's an accurate measure? What are some possible errors in the procedure we used?
Answers will vary. Some factors that will affect accuracy are incorrect identification of plants, incorrect counting of plants, and lack of randomness of the sample. If different people compile measurements on different transects the same results may vary.

Extending these calculations

You can calculate a more precise measurement of wetland diversity if you can identify native and exotic species. The calculations, and values calculated using the examples, are given below:

The basic Diversity Index, DI_0, was shown above and is calculated as

$$DI_0 = \frac{\text{total \# of runs}}{\text{total \# of plants}}$$

The Modified Diversity Index, DI_M, compares the diversity index of native plants to the total plant population and is calculated as

$$DI_M = \frac{\text{total \# of runs of native species}}{\text{total \# of runs}}$$

The Species Diversity Index, DI_S, gives the diversity index for different species and is calculated as

$$DI_S = \frac{\text{total \# of different species}}{\text{total \# of runs}}$$

The Diversity Index of Exotic species, DI_E, is calculated by taking the square root of the basic Diversity Index times the Modified Diversity Index:

$$DI_E = \sqrt{(DI_0 * DI_M)}$$

These indices can be used to give an Overall Diversity Index, DI_O, which will give a more precise measure of site diversity. It is calculated by taking the cubic root of the basic Diversity Index times the Modified Diversity Index times the Species Diversity Index (or the Diversity Index of Exotic species, if that is your chosen focus):

$$DI_O = \sqrt[3]{(DI_0 * DI_M * DI_S)} \qquad \text{or} \qquad DI_O = \sqrt[3]{(DI_0 * DI_M * DI_E)}$$

If you choose to calculate the Overall Diversity Index perform the calculations for each of three transects separately and then average the three indices to give you the most accurate value.

Notes

Activity Four
Is Purple Loosestrife a Problem in Our County?

Leader Summary Sheet

General Description

Students will learn to identify purple loosestrife, study the progress of local infestations, and record the observations that they make. Youth can locate wetlands by studying aerial photographs or by taking a walking, bicycle, or automobile tour. Local professionals may be able to help you locate areas that have a problem with purple loosestrife infestations.

Season

July-mid August is best for locating the plants

Estimated Time

several days

Materials

- Reference materials
- Loosestrife Locator Data Sheet
- Maps (road, soils, USGS topographic)—from county Extension office
- Different colored pens to mark maps
- People to interview or guest speaker (county Extension educator, state natural resource agency personnel, university professor, state environmental agency, etc)

Reflect - Why is it important to determine if your county has a purple loosestrife infestation and how extensive any problem is?

Generalize - Why is it important to be able to identify if a problem exists before beginning to work on it?

Apply - How does learning to identify the source and extent of a problem help you in solving them?

Extension of this lesson

4-Her can plot patches of other wetland plant species (e.g. cattails, sedges, willows) on a map and make comparisons between the extent of purple loosestrife and other wetland plant species. This activity would be a good connection with Activity 3 (Annual Wetland Diversity Survey). The students can explore the relationship of high-density purple loosestrife areas to the diversity of other wetland plant species.

Lythrum Salicaria -Spiked or Purple Loosestrife (botanical description)

- Perinnial
  - erect glabrous or pubescent, sometimes tomentose above, at length much branched
  - 6-7' high and about 4' wide
  - 30-50 herbaceous stems for a common stalk
- Leaves
  - opposite or sometimes whorled (circling the stem)
- Flowers
  - purple, trimorphous, 6"-8" broad, in dense compound terminal interrupted bracted spikes; stamens 8-10, alternatley longer & shorter, even the longer ones little exserted; ovary short-stalked; fruit calyx about 3" long; clayx-lobes shorter than the narrow appendages.
- In swamps & wet meadows
  - naturalized from Europe, widely distributed in the Old World, spiked willow herb, long purples, soldiers; Purple-grass, Willow-or-killweed, Sage-willow,
    Milk or purple willow-herb, Red sally, Rainbow-weed

Loosestrife Locator Data Sheet

Name: _____

Address: _____

Phone: _____ Email: _____

County: _____ Nearest Town: _____

Nearest Cross Roads: _____ & _____

- The purple loosestrife patch can/cannot (circle one) be seen to the NE/NW/SE/SW (circle one) from the intersection.
- It is more/less (circle one) than a "stone's throw away."
- Check and circle all that apply to a description of the site:

_____ Wetland/Marsh _____ Roadside/Ditch

_____ Lake/Pond Edge _____ Other (describe)

- This patch is smaller/larger (circle one) than one acre (about the size of a football field)

Total Number of Plants: Total Size of Infestation:

_____ 10-100 plants _____ 10-100 yards long/across

_____ more than 100 plants _____ more than 100 yards long/across

activity 4

Is Purple Loosestrife a Problem in Our County?

Objectives

- Examine the historical spread of purple loosestrife.
- Collect data on the current distribution of purple loosestrife in the county.
- Predict the impact and future spread of purple loosestrife.

Past: Examining the Historical Record

Gather information about the historical spread of purple loosestrife in the U.S..

- Use reference books, newspapers, or the Internet to learn how and when purple loosestrife arrived in the U.S.. How has it spread? How do you think it got into your county?
- Interview people living in the area where there is a purple loosestrife infestation. What do the wetland neighbors say? Find out what they remember about the plant. How long has it been there? How fast have the numbers increased?

Purple loosestrife is a native wetland plant in Europe. It is thought to have arrived in North America along the east coast as early as 1800. Seeds and plant fragments were transported in ship's ballasts. Some seeds may have arrived mixed in bags of grain and in the fleece of sheep. Purple loosestrife was also introduced intentionally as a medicinal herb, landscape flower, and nectar source for honeybees.

To help settle the new land, immigrants began building a network of canals to inland areas in the 1800s. These canals were perfect for the invasion of purple loosestrife for two reasons. The first reason is that these canals and the ships traveling on them made the transport and dispersal of seeds easy. The second reason is that building the canals created huge areas of disturbed wetlands for purple loosestrife to invade. Purple loosestrife is now found in all of the contiguous states in the U.S., except Florida.

Purple loosestrife has a life cycle well adapted to wetlands. It spreads to new areas primarily by the dispersal of seeds. Purple loosestrife seeds are very small and extremely numerous. Some seeds float between wetlands. Others will sink to the bottom of the wetland and then rise to the surface after germination to be dispersed as floating seedlings. Many of the seeds are mixed with the wetland soil and then dispersed by animals, such as deer, or by tires of off-road vehicles, or by the boots of hunters. Seeds may also be dispersed by wind, by sticking to the feathers of birds, or by being eaten by animals and then deposited in other wetlands in their droppings. Because of these many dispersal strategies, purple loosestrife easily spreads from one wetland to another. Purple loosestrife seeds are viable up to three years, have an 80% germination rate, and can germinate in a wide range of soil conditions.

Once a seed finds a suitable location, it will begin to grow roots, stems, and leaves. Eventually (3-5 years) the plant will develop a large root crown made up of many stems. The plants grow

very closely to each other and form a stand so dense that it crowds out the native plants. There are about 1,000 seed capsules per stem and about 90 seeds per seed capsule. This means that one mature plant can produce more than 2 million seeds each year!

Another adaptation that allows purple loosestrife to be such a successful invader is that it thrives in disturbed areas. When the root crowns of purple loosestrife are damaged by trampling, machinery, or other means, the injured roots will send up even more new stems.

Until natural enemies were brought to North America, the species grew out of control.

Present: The Current Distribution of Purple Loosestrife

To devise a comprehensive plan for the control of purple loosestrife in wetlands, it is necessary to know the location of local wetlands and loosestrife patches. It is also important to note the extent and density of the purple loosestrife infestation in those wetlands. Different means of control may be used depending on the size of loosestrife patches and their density.

- Use the Loosestrife Locator Cards (Appendix J) to record where you find distinct patches of purple loosestrife within your county. Plot all of the purple loosestrife patches on a map.

  Alternatives: Assign pairs of students to a specific area. Go as a group to different parts of the county. Join with other 4-H groups to collect data throughout the county. You could encourage other members of the community to help fill out Loosestrife Locator Cards. You can determine the part of the county you want your group to survey.

  You could use different colors of markers to identify the different densities or sizes of purple loosestrife infections in the county on a county map.

- How is purple loosestrife distributed in your county? Do you notice any patterns?
  Answers will vary depending on your county situation.

Future: Predicting the Spread and Impact of Purple Loosestrife

The Federal Government is working to reduce the spread of purple loosestrife and other exotic species, by the careful monitoring of ship ballasts and restricting the transfer of the plant. You are helping to control the spread of purple loosestrife by being involved in this 4-H activity. Besides raising and releasing the *Galerucella* beetles (described later in this manual) you can try to predict which ecosystems purple loosestrife will invade next. By working to keep the plant out of local wetlands, you can help reduce the ecological impact purple loosestrife may have in your area.

- Predict the next area(s) that may be invaded by purple loosestrife.
  Answers will vary since the students are making predictions.
- Predict the impact that purple loosestrife may have on a wetland ecosystem.
  Answers will vary. The students could examine the impact of purple loosestrife habitat, other wetland plants/animals, etc.

Activity Five
Controlling Purple Loosestrife

Leader Summary Sheet

General Description

Rarely is there one solution to a problem. Usually there are several possible solutions, and sometimes a combination of solutions is best. Control strategies for purple loosestrife depend on the extent of the infestation (area and density), human resources, financial resources, and other factors. Youth will brainstorm solutions to the purple loosestrife problem. They will discuss the benefits and risks associated with each solution and will try to choose the best solution, or combination of solutions, to reducing the amount of purple loosestrife in local wetlands.

Season

Spring/Summer/Fall

Estimated Time

1 hour

Materials

None

Reflect - Why is it important to determine the best solution for the purple loosestrife infestation in your county?

Generalize - Why is it important to be able to identify more than one solution and determine the solution that will work best for you?

Apply - How can thinking about different possible solutions help you in your classes (mathematics, science, etc.)?

Additional Information

- Appendix A: *Removing Purple Loosestrife by Hand*
- Appendix B: *Purple Loosestrife Control Options*
- Appendix C: *Natural Enemies to Control Purple Loosestrife*

Recommendations

The choices that property managers will consider for controlling purple loosestrife are generally based on the size of the infestation. The following recommended solutions are based on the number of purple loosestrife plants in the wetland (or sometimes along a stream).

Number of Plants	less than 25	25 - 100	100 - 500	more than 500
Management Solutions	dig	spray cut flower heads * burning	use insects ** spray burning cut flower heads *	use insects ** burning

* You can prevent seed set (and, consequently, the production of seeds) by cutting all the flowers as soon as you see the first bloom. If you choose this control method you must return to the wetland multiple times, because the plants will continue to try to make flowers in an effort to set seed.

** Introduce specific insects from its native ecosystem to act as a biological control.

For Further Discussion

The three site descriptions given below suggest different management solutions and may help youth think about the risks and benefits of various control solutions.

Site 1: Purple loosestrife has invaded all the low-lying areas near a pond in a subdivision. Homeowners are able to control the plants that begin growing on their own property by digging them out. The Homeowners' Association owns approximately a half-mile of pond frontage, in which purple loosestrife has become very dense. Homeowners have asked the Association to remove the loosestrife because they believe that the seeds from the infestation are re-infesting their properties. The Association does not have the funds to hire someone to remove the loosestrife. How would you recommend this situation be handled?

Suggested answers: hold a community work day to remove the loosestrife; ask a 4-H or school class to remove the loosestrife as a community service project; hire someone and assess each homeowner their portion of the fee (get estimates on mechanical, chemical, and biological controls).

Site 2: A farmer was checking an area she maintains in a natural state for wildlife. This year she noted about a half acre of purple loosestrife in her wetland. The farmer has only limited funds and limited time to deal with this invasion. She would like to remove all the loosestrife so that it does not destroy all the native plants that supply habitat needs for wildlife. What would be the best way to control the loosestrife?

Suggested answers: ask a 4-H or school class to remove the loosestrife as a community service project; use mechanical methods (plowing & mowing) to remove the loosestrife if the area is dry enough. Note - since the farmer wants to protect the area for wildlife, chemical methods of control should not be used.

Site 3: You have just bought a house in the country and found approximately 150 purple loosestrife plants along a stream between your property and your neighbor's property. When you spoke to your new neighbor he indicated that he had planted the loosestrife a few years before because of its beautiful flower. Would you ask your new neighbor to destroy the loosestrife? How would you discuss this with your new neighbor?

Suggested answer: This situation needs to be handled tactfully so that relations with the neighbor are not ruined. You might suggest that biological controls are used to keep the plant from spreading all along the stream and into other areas on your properties. Explain that biological controls will hold the plant in check, rather than destroy it completely. In Europe, loosestrife is common, but not dominant. You might offer to plant a native species along the stream.

activity 5

Controlling Purple Loosestrife

Objectives

- Develop solutions to control the spread of purple loosestrife.
- Discuss benefits and risks associated with each control strategy.

Focus questions

1.) How does purple loosestrife invade wetlands?

Because purple loosestrife is an exotic plant (not native) in North America, it has no natural enemies in North American wetlands. It has several natural enemies in Europe so it does not dominate wetlands there. Purple loosestrife can spread rapidly through seeds and roots when there are no natural enemies to control it. Purple loosestrife roots get bigger each year. As the roots get bigger, they make more stems, leaves, flowers, and seeds. These bigger plants take up more room than smaller plants. One purple loosestrife plant can produce over 2 million seeds. These seeds travel to other wetlands by floating in the water or by mixing with the wetland mud, which then sticks to animals that walk through the wetland.

In wetlands where there are too many purple loosestrife plants, there isn't enough room for native plants and animals to live. We already learned that a high purple loosestrife population density could reduce the diversity of the wetland plant community.

2.) Is there any way to control the spread of purple loosestrife?

Brainstorm control strategies to stop or slow down the spread of purple loosestrife in wetlands. Possible answers include:

- *Burning*
- *Cutting the flowers before seeds set*
- *Spraying herbicides*
- *Digging plants*
- *Doing nothing*
- *Biological control (If students don't mention this one, don't introduce it until the end of the lesson. If students allude to it, tell the group they will learn more about it in the next session.)*

Sometimes the best control is obtained by using a combination of the strategies mentioned.

3.) How do land managers find an appropriate control strategy? What are some criteria that they use to select the best strategy or strategies?

Land managers must select the best control strategy (or strategies) for controlling purple loosestrife infestations. Depending on the position and extent of the problem they may use any one (or more than one) strategy that you discussed in question number 2. What considerations can you think of that the land manager would need to consider before beginning any control procedure?

Some possible answers are:

- *Does the solution control purple loosestrife?*
- *Does it harm other plants and animals?*
- *Does it cost too much money?*
- *Does it take too much time?*
- *Does it have to be done annually (or even more frequently) and indefinitely?*
- *Is it a long-term solution?*

4.) Discuss the benefits and risks associated with each of the control strategies you listed above.

Have the students make a chart to evaluate the control strategies. The chart could be a checklist to see if the strategy meets the criteria listed above. The students should also list the benefits/risks associated with each control strategy. Discuss the control methods with the 4-Hers and brainstorm benefits and risks of each method. You may be able to help them by discussing the questions in #3 (above).

Solutions	Risks/Drawbacks	Benefits
Burning	*fire* *does not affect roots*	*low cost, low labor needs*
Spraying with herbicides	*removes native competitors* *expensive for large areas*	*low labor needs* *possible cost effective*
Digging	*labor intensive*	*affects target species only* *non-chemical control*
Cutting flower heads	*labor intensive*	*affects target species only* *non-chemical control*
Natural enemies	*medium labor needs* *slower effects*	*affects target species only* *biological control*
Doing nothing	*purple loosestrife will take over*	*no cost, no labor*

5.) Which strategy or strategies would you suggest using to control purple loosestrife in your wetland area? Why?

Have the students discuss their choices. Present the chart provided in the Recommendation section of the Leader Summary Sheet to show students which strategies land managers use. Introduce the concept of biological control.

Notes

Activity Six
Biological Control of Purple Loosestrife

Leader Summary Sheet

Objective

Present a benefit and cost analysis of biological control of purple loosestrife to your community. *(Suggested target audience is the local media)*

General Description

Students learn about biological control. They will research the solution and develop a community awareness program.

Season

Spring/Summer/Fall

Estimated Time

1-2 hours

Materials

- Information on *Galerucella* (see the websites listed in the front-pages of this manual)
- Appendix B: *Purple Loosestrife Control Options*
- Appendix C: *Natural Enemies to Control Purple Loosestrife*
- Materials needed to make pamphlets, posters, video, etc.

Reflect - Why is it important to determine the benefit and costs of using a biological control of purple loosestrife before you start?

Generalize - Why is it important to think about potential benefits as well as costs before starting almost any new project?

Apply - How can a cost/benefit analysis help you in making life decisions (i.e. if you should buy a car)?

activity 6

Biological Control of Purple Loosestrife

Objectives

- Conduct a benefit and cost analysis of using a biological control agent to manage purple loosestrife.
- Understand biological control and why it is a good solution to the purple loosestrife problem.
- Educate your community about biological control of purple loosestrife.

Biological Control

Biological control means using living organisms to control other organisms. The organism used to control another organism is called the biological control agent. The organism being controlled is called the target organism.

What is the target organism in our wetland system? Purple Loosestrife

Benefit/Cost Analysis

Before a biological control effort can be recommended, the costs, risks, and benefits of the program must be studied. Complete the following problems to assess the benefits and costs of using a biological control on purple loosestrife. The scenarios in this activity are based on actual estimates.

Potential Gains From Biological Control

A.) It is estimated that 1,233,000 acres of wetlands are at risk of purple loosestrife infestation in the central and eastern U.S. Assume that these wetlands have an average value of $300/acre and that 5% of them are damaged by purple loosestrife each year so that they are worth nothing. What would be the land value of the wetlands lost to purple loosestrife in a year? What would be the cost of the loss of wetlands after 20 years?

*After one year: 1,233,000 acres * 0.05 * $300.00/acre = $18,495,000*
*After 20 years: 1,233,000 acre * 1.0 * $300.00/acre = $369,900,000*
*Note (5%/yr * 20 years = 1.0)*

B.) Muskrats provide fur for the market at a rate of 5,204,461 pelts/year. Each pelt is worth an average of $2.69. Muskrats need cattails for food and cover, but cattails are generally out-competed by purple loosestrife. If purple loosestrife replaces the cattail population in the U.S., what is the potential yearly loss of pelt revenue (to the nearest dollar)?

*5,204,461 pelts/year * $2.69/pelt = $14,000,000 each year*

C.) The money people spend in recreational pursuits is one way to determine the value of a resource. Consider the following two uses of wildlife:

1.) Consumptive Wildlife Use

Assume that there are 500,000 migratory bird hunters, and each hunter spends an average of $120/year. Half of the money spent by hunters involves hunting birds that utilize wetlands. What would the potential loss of revenue from bird hunters be if all wetlands were invaded by purple loosestrife, which caused a loss of habitat and, consequently, a loss of half the game birds after 20 years (as in part A)? Assume that the loss of game birds result in a decrease in hunting (by half). What would the average annual loss be?

*500,000 hunters * $120 * 0.5(% birds affected) = $ 30,000,000*
$30,000,000/20 = $1,500,000/year

2.) Non-Consumptive Wildlife Use:

During any given year, an estimated 12.6 million people visit wild places to photograph, bird watch, or just "get away from it all." Assume that each visitor spends an average of $129.86/year, and approximately 10% of the visits are to a marsh or other wetland. What is the potential annual lost revenue, assuming that visitors do not want to see only purple loosestrife and 10% stop going to the marshes and wetlands?

*12,600,000 people * $129.86/person * 0.1(percent loss) = $163,623,600*

D.) Find the potential annual resource value lost.

1) Add the values that you calculated for sections A, B, and C for wetlands that decline due to purple loosestrife infestation.

$18,495,000 + = $14,000,000 + $1,500,000 + $163,623,600 = $197,618,600 yearly

2) Olf the purple loosestrife biological control program can save 20% of this annual resource value, then how much money will be saved?

*$197,618,600 * 0.2 (percent saved) = 39,523,720 yearly*

Potential Losses From Biological Control

E.) The cost of developing and running the purple loosestrife biological control program to date has been approximately $1,200,000. This includes research in Europe looking for appropriate biological control insects, research on the insects found, and rearing and release of biological control organisms. Assuming that this research began in 1990, what is the average yearly cost in the year 2000 (to the nearest dollar)?

$1,200,000/11 (must include 1990 & 2000) = $ 109,091 per year

F.) Purple loosestrife is an excellent source of nectar, so bees use it regularly during the blooming season. Annual sales of honey amount to $12,820,000. If purple loosestrife did not exist in wetlands, an estimated 10% of this revenue would be lost. What is the potential total honey revenue lost?

*$12,820,000 * 0.1 = $ 1,282,000 each year*

G.) Purple loosestrife is also a sought-after ornamental. While it has been declared a noxious weed in many states, it is still available on the market as a "sterile cultivar." If this cultivar also became illegal, as some people recommend, then $300,000 in sales would be lost each year.

$ 300,000 each year

H.) Find the total annual cost (E + F + G) of losing purple loosestrife.

$ 109,091 + $ 1,282,000 + $ 300,000 = $ 1,691,091 each year

I.) Find the yearly benefit-cost ratio (benefits, D-2, divided by costs, H) to the nearest decimal point.

$39,523,720/ $1,691,091 = 23.4

Our calculations show an estimated 23 units of benefit for each unit of cost. When the benefit/cost ratio is high (how high depends on many factors, such as total cost, the ease of implementing the benefit, etc.) the benefit is generally implemented. This is the case with using biological control to manage purple loosestrife infestations.

Selecting a Biological Control Agent

When selecting biological control agents, scientists choose a natural enemy of the organism needing to be controlled. For purple loosestrife, scientists traveled to Europe where purple loosestrife is a native plant, to search for possible biological control agents. They identified more than 120 kinds of insects that are natural enemies of purple loosestrife in Europe. They tested many of these insects while considering the following questions:

- Does the *Galercuella* beetle live only on purple loosestrife and not any other native plants?
- Is it harmful to humans or other organisms (i.e. are they safe)?
- Can it survive year round in the new environment?
- Can it be easily and cheaply raised?

1.) Why are these questions important when selecting a biological control agent?

We are releasing a non-native organism into the environment. We have to make sure that these organisms will not create a new problem. Land managers are also concerned about costs. Labor-intensive solutions are less favorable.

2.) Visit the websites listed below to learn more about purple loosestrife, biological control, and the *Galerucella* beetle. These sites will help you answer the questions below.

www.state.in.us/dnr/entomolo/purple2.htm
www.inhs.uiuc.edu/cbd/loosestrife/bcpl.html
www.msue.msu.edu/seagrant/pp/
www.nysaes.cornell.edu/ent/biocontrol/weedfeeders/galerucella.html
www.uoguelph.ca/~obcp/

- Does the Galerucella beetle live only on purple loosestrife and not any other native plants?

  Galerucella beetles eat lots of purple loosestrife and consume other plants on a very limited basis. Both the adults and the larvae of the beetles eat purple loosestrife.

- Is it harmful to humans or other organisms (i.e. are they safe)?

  Scientists tested the beetles and found that they rarely eat anything except purple loosestrife and lay their eggs on purple loosestrife. They placed hungry adults and larvae of beetles inside cages and tried to get them to eat other plants and many beetles starved to death. This is very important when choosing a natural enemy. An animal that eats only one kind of organism, such as the beetle that only eats purple loosestrife, is called a specialist. An animal that eats many kinds of other organisms is called a generalist. Most animals used in biological control programs are specialists so they are not harmful to other organisms.

- Can it survive year round in the new environment?

  Because the beetles are native to the temperate deciduous forest of Europe (where the climate is similar to that in much of North America), they can survive year round after they are released into our wetlands. Once they are released into wetlands where purple loosestrife grows, the beetles can maintain their life cycle every year.

- Can it be easily and cheaply raised?

  Scientists have found that many of the natural enemies of purple loosestrife are difficult and/or expensive to raise in large numbers. The Galerucella beetles can be easily raised in laboratories, greenhouses, and classrooms by growing purple loosestrife plants in pots and then letting the beetles live on the plants. The beetles can't escape because a screen bag is placed over the potted plant. The beetles complete their entire life cycle on these potted plants and can be released into wetlands where purple loosestrife is growing and the colony multiplies.

3.) Do you think the Galerucella beetle was a good choice as a biological control agent for purple loosestrife?

The Galerucella beetle was a good choice for the reasons outlined above. The students should be able to explain the choice of the beetle to others in the community.

Educating the Public

Now that you have learned so much about the purple loosestrife invasion of wetlands and the costs and reasons for control you should begin thinking about sharing your knowledge with your community. Most citizens are probably not aware of the purple loosestrife problem. They need to understand why people are using biological control with Galerucella beetles. What questions might members of your community have? How would you answer those questions?

Brainstorm questions as a group. Research and develop answers to those questions. Focus on the questions that are most important to your group and your community.

You can help your 4-Her collect and develop materials to educate members of your community about biological control of purple loosestrife. You might make a poster, pamphlet, video presentation, or other media display. Your 4-H group could produce a community awareness exhibit. Your work could also be presented in a 4-H fair display, or to the press, or present your findings to your Town Council or other county or community administration.

Notes

Activity Seven
Biological Control Agent: Host-Plant Specificity

Leader Summary Sheet

General Description

"Host-plant specificity" refers to whether the *Galerucella* beetles will eat a wide range of plants or whether they limit their feeding to specific plants. When they perform this activity, youth will learn how selectively *Galerucella* beetles eat. They will feed the beetles various plants (i.e. purple loosestrife, lettuce, grass, cabbage, and anything else that you can find) and note what the beetles eat.

If you can obtain enough beetles, let each 4-Her take their petri dish home and do their own study. You may not be able to do this activity until you can get beetles locally. (Do not use the beetles you are raising as you want to be as healthy as possilbe.).

Season

Any time, when beetles are available

Estimated Time

from 2-3 days to one week

Materials

- purple loosestrife
- vegetation (i.e. lettuce, grass, cabbage, and anything else that you can find)
- Petri dishes or similar covered container
- filter paper (coffee filters cut to size will work)

Reflect - Why are people concerned that *Galerucella* beetles might eat plants other than purple loosestrife?

Generalize - Why is it important to consider potential negative impacts of introducing a non-native species in your community?

Apply - How can you explain plant specificity and *Galerucella* beetles to concerned citizens?

Additional Information

Youth should note that the *Galerucella* beetles are highly selective to the purple loosestrife plant. Host plant specificity is a very important trait to test before bringing a non-native species to the U.S. to control another species. A high level of host-plant specificity assures that a species will not move to native plants when the purple loosestrife populations begin to decline. When purple loosestrife populations decrease, the *Galerucella* beetle populations will decline. Scientists are very concerned that they do not introduce another problem species when trying to control purple loosestrife.

activity 7

Biological Control Agent: Host-Plant Specificity

Objectives

- Test whether a biological control agent will feed on plants other than purple loosestrife.
- Assess the chances that the biological control agents will eat native species of plants.

Identifying the Problem

Assume that you are working for the Plant Protection and Quarantine Service of the U.S. Department of Agriculture. You have been sent a new species of beetles, *Galerucella calmariensis*, which are to be tested before potential release as a biological control agent against purple loosestrife. Before any release can be made, the specificity of the agents must be assessed and then a decision made as to the safety of the agent. "Specificity" refers to whether the beetle will eat a wide range of plants or whether it eats only specific plants.

Does the beetle being preposed as biological control agent for release against purple loosestrife show host specificity (choose to eat only purple loosestrife)? How safe will it be when released into your wetland? Will the beetle eat native plants? To determine the answers to these questions, you will conduct a choice test. In a choice test, the biological control agent (*Galerucella*) is tested using the target plant (purple loosestrife) and several other plant species. Biological control agents with a broad host range (those that eat many species related to the target) may have a deleterious impact on non-target species. In contrast, those with a fairly narrow host range will probably have few, if any impacts on non-targets. You will need to determine if *Galerucella* beetles have a narrow or broad host range. This will help you decide if the beetles should be released in our wetlands.

Scientist generally conduct no-choice tests as well as choice tests. In a no-choice test, the biological control agent is given just one plant to see if it will eat the plant when there are no other choices.

Procedure

1.) Place about one square inch pieces of 5-10 leaves of different plants in a Petri dish (Be sure that one leaf piece is purple loosestrife.)

2.) Place filter paper in the bottom of the Petri dish. Arrange the leaf pieces around the Petri dish, at least 1 cm from the outside edge. Label the leaves in the dish.

3.) Slightly wet the filter paper to keep the leaves from drying out. Wet the paper each day by raising one side of the dish lid and adding very little water.

4.) Place 5-10 beetles in the center of the dish and cover with the lid. Keep in a warm place (room temperature or above) but not in direct sunlight.

5.) After a few days, remove the lid and assess the feeding. *Galerucella* beetles feed by chewing holes in leaves, so you will estimate the percent of damage. Record your observations in a data table.

Photo: Pat Charlebois, Illinois-Indiana Sea Grant/Illinois Natural History Survey

Data Table

Plant Species	Percent (%) of Feeding Damage

Activity Eight
Purple Loosestrife & *Galerucella* Beetle Rearing

Leader Summary Sheet

General Description

Students will grow a purple loosestrife plant, then place about 25 *Galerucella* beetles on it to establish a colony. *Galerucella* beetle populations can be substantially increased in a few months if provided nutrition and protection from predators. This activity describes outdoor rearing. See Appendix D if you wish to raise beetles indoors.

Season

Spring-Summer

Estimated Time

2-3 hours to set up. Plant monitoring is required daily.

Materials

These list the materials you need as well as the estimated cost

- See Appendix D: *Raising Galerucella Beetles Indoors*
- See Appendix E: *Outdoor Rearing of Galerucella Beetles.*

Reflect - Why are scientists interested in having youth and adult volunteers help with raising beetles? How do scientists and resource managers breed natural enemies of purple loosestrife? If we wish to nurture them, what special care must be taken with purple loosestrife's natural enemies?

Generalize - How do volunteers affect community service projects in your county?

Apply - How do you help your community (i.e. school, church, environmental neighborhood, county, etc.) through volunteerism?

Additional Information

This activity can be a good introductory activity for this project because it gives the 4-Hers a hands-on experience and enhances their learning in later activities. You can raise the *Galerucella* beetles inside (if you have enough room) or outside once the temperature permits (late May to July). It is important to time this activity so you have beetles to release at your wetland at the appropriate time (June through August, in the Midwest).

The Student Activity Book provides minimal instructions for this activity. You will find more detailed information in Appendices D and E.

Activities Nine and Ten (Observations & Life Cycles) are related to this activity. After setting up their first few pots, the 4-Hers should read Activity Nine to learn what they will do next.

Youth will benefit from watching how quickly the purple loosestrife plant grows and the stages of the beetles life cycle. Try to have the 4-Hers see the plant daily for the first week (after you plant and water it) and to check the beetles at least weekly.

You might want the group to produce an observation journal in addition to, or in place of, their individual observations in their book. Further details about beetle rearing can be found in Appendices D and E.

activity 8

Purple Loosestrife & *Galerucella* Beetle Rearing

Objectives

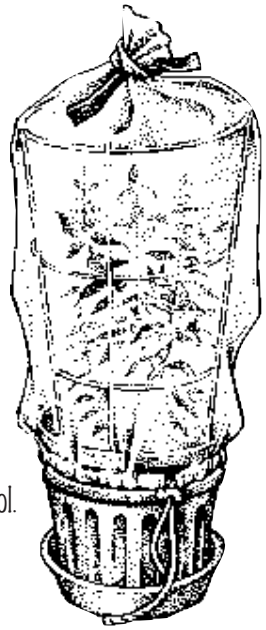
- Learn techniques for rearing purple loosestrife plants and *Galerucella* beetles.
- Raise beetles for release into wetland areas. This takes about two to three months (one month to grow purple loosestrife and one or two months to raise the beetles).

Note: In the Midwest you should time your beetle rearing so they are ready to be introduced to the designated wetland in June-August.

Growing Your Plant

A.) Potting the Root Crown

1.) Put a 4-gallon pot into the kiddie wading pool. The pot should have holes in it so the plant can be watered from below. (Note - one 4-H leader made her own pots with 5 gallon plastic buckets. She drilled 6 holes on the bottom and 4 holes on the sides, 2 inches above the bottom for water uptake.)



2.) Fill the pot half full with a non-soil potting mix.

3.) Sprinkle a tablespoon of slow-release fertilizer and mix into the soil.

4.) Place the root crown into the soil. Make sure the stems are pointed upwards.

5.) Fill the remainder of the pot with potting soil.

6.) Tap the pot to settle the soil, but do not pack it down.

7.) Water the plant thoroughly ONCE from the top and put 2-3 inches of water in the pool.

B.) Setting up the Plant Cage

1.) Place a tomato cage into the pot and press down firmly to seat it.

2.) Tape the sharp edges and joints of the tomato cage so they won't tear the fabric (sleeve).

3.) Place a fine mesh sleeve over the cage. Secure the top and bottom with twine, tape, or a heavy rubber band. (Note - one 4-H leader used a truck tire inner tube (cut cross-ways into 1/2 inch circles) as the 'rubber band' to hold the net on the bucket.

4.) Place the plant where it will receive the most sunlight.

C.) Maintaining the Plant

1.) Refill the pool as needed to maintain a water depth of 2-3 inches. DO NOT water the plants from the top.

2.) Pinch off the tips of stems reaching the top of your cage. (This may not be necessary if you introduce the beetles before the stem tips reach the top of the cage. The beetles will stop this growth.)

3.) Keep your plant in full sun to be sure to allow air movement around it.

D.) Infesting Purple Loosestrife with Beetles

1.) When the plant is about 24 inches tall, place 20-25 adult *Galerucella* beetles into the cage.

2.) Make sure that the beetles receive at least 16 hours of light daily and plenty of air flow. (Beetles can die from fungus under very humid conditions.)

3.) Continue to monitor your plant to be sure it has light and water.

Notes

Steps for making a sleeve for your plant cage:

- Cut a fine mesh (approximately 20 x24 squares per inch or smaller) fabric 48" x 54" (4 x 4.5 ft^2).
- Fold the fabric to give a 24"x54" rectangle.
- Sew the open side and top, leaving the bottom open.
- If you will be using a drawstring, fold the top and bottom edges 1" and sew to make an envelop for the string
- Slip this sleeve over the tomato cage and secure it so that the beetles can not get out.

You can raise two generations of beetles to increase the impact on your wetland. Note that you will need to begin this activity in January or February indoors (see Appendix D) in the Midwest to have the second generation ready to be placed in the wetland in June. If you raise beetles in five pots, for example, your wetland inoculation colony should produce between 2,500and 7,500 beetles. Ten pots would produce approximately 5,000 to 15,000 beetles.

If all goes well, your beetles will produce 200-2,000 offspring!

Photo: Pat Charlebois, Illinois-Indiana Sea Grant/Illinois Natural History Survey

Activity Nine
Observations & Life Cycles

Leader Summary Sheet

General Description

Youth will periodically make observations of the purple loosestrife and beetles they nurture in the pots. Through their observations, they will learn more about the purple loosestrife and *Galerucella* beetle life cycles. They will also see the damage the beetles cause to the purple loosestrife plant. Youth should also think about how abiotic factors (temperature, sunlight, etc.) affect the growth of purple loosestrife and the behavior of the beetles.

Season

Spring-Summer

Estimated Time

30 minutes/observation

Materials

- purple loosestrife plant
- *Galerucella* beetles

Reflect - What can you learn by watching the growth of a purple loosestrife plant and an insect life cycle?

Generalize - Why is it useful to understand plant and insect growth when you are working on a biological control program?

Apply - How does an understanding of plant and insect development cycles help you control them (e.g. mosquitoes, fleas, multiflora roses, etc.)?

Additional Information

This activity corresponds to Activities Eight and Ten. The students need to have a purple loosestrife pot with beetles to observe.

Appendix F: *Life History and Ecology of Galerucella calmeriensis and G. pusilla*
Appendix G: *Life History and Ecology of Hylobius transversovittatus*

At critical stages of the Indoor Purple Loosestrife/Beetle Raising, invite the students to make observations. The plant grows very quickly a first so daily observations are recommended for the first week after you start the plant. You might want the group to produce an observation journal in addition to or in place of their individual observations in their book.

After the students sketch each beetle life stage based on their observations, encourage them to compare the purple loosestrife and beetle life cycles.

Sample Data Sheet

Date	Temperature (°C)	Humidity	Rainfall (cm)	Height of Plant (cm)

activity 9

Observations & Life Cycles

Objectives

- Observe the growth of purple loosestrife and the life cycle of *Galerucella* beetles.
- Collect and organize data based on your observations.
- Formulate questions about the purple loosestrife plants and the beetles.

Data Collection

When you raise plants and animals, it is important to monitor their growing conditions. Good observations will help you determine the optimum growing conditions for the plants and animals.

A.) Abiotic Conditions

Abiotic factors are the non-living components of the environment, such as temperature, cloudiness, humidity, amount of light, etc. Abiotic factors can impact the growth of plants and the behavior of animals. Your group should determine which abiotic factors you want to record. An example of a data table is given in Activity Eight.

B.) Purple Loosestrife

Sketch the purple loosestrife plant as it looked when you started, and when you introduced the beetles. Measure the growth (height) of the purple loosestrife plants. Include this data in your data table from Part A. Also, note the appearance of the plants and their leaves over time. Create a data table to record your observations.

C.) *Galerucella* Beetles

Observe the stages of the *Galerucella* beetle life cycle. Make a sketch of each life stage. Compare the *Galerucella* beetle life cycle with the purple loosestrife life cycle. An example of the beetle life cycle is shown on page 40.

D.) Data Analysis

Create a graph to represent some of the data your group collected. Interpret the graph. What does it tell you about purple loosestrife or the beetles?

E.) Focus Questions

Watching the purple loosestrife plants and beetles grow may cause you to ask many questions, like those given below. Try to think of questions that you can share with your group.

- What is the impact of the beetles on the purple loosestrife plants?
- How do the abiotic factors impact the growth of purple loosestrife?
- How long did it take before the new adult (second generation) beetles appeared? What was the average daily soil temperature during this time?

Purple Loosestrife Growth

Sketch the purple loosestrife plant when you first saw it:

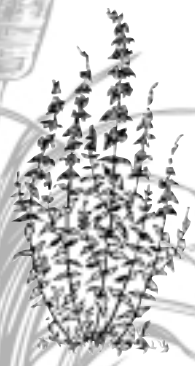
Use the following data chart (or make your own) to record the plant growth and abiotic conditions:

Example

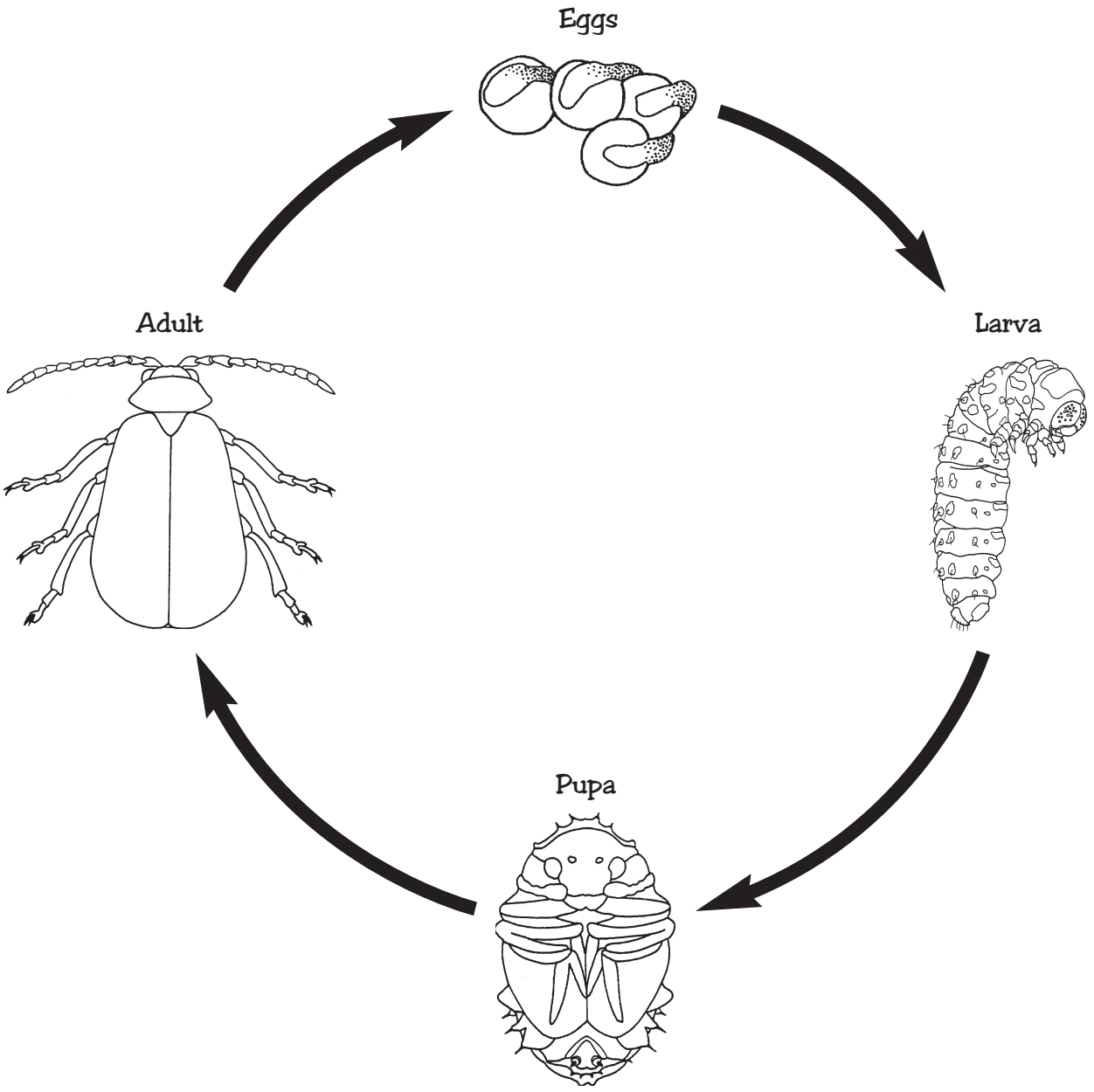
Date	Plant growth (can include any/all of the following: plant height, temperature, humidity, hours of darkness, soil temperature, etc.)

Notes: *Other abiotic conditions that you might want to record (in addition to or in place of those given above) could include: amount of water offered, amount of fertilizer added, hours of artificial light and hours of daylight. Also, if the plants are grown in a greenhouse a hand lens should be used weekly to check for unwanted insects and diseases and the plants will need to be shaded from June to September.*

Sketch the purple loosestrife plant when you introduced the beetles:



Galerucella Beetle Life Cycle



Activity Ten
Galerucella Beetle Release

Leader Summary Sheet

General Description

Students will release the beetles they raised into the wetland area that they have been studying. Try to have the release timed for June through August in the midwestern states.

Season

late June – early August

Estimated Time

One hour

Materials

See Wetland Plant Diversity Survey to review how to determine the Diversity Index

Copies of "Wetland Plant Diversity" Data Sheet (at the end of this activity)

Reflect - Why did you record data about conditions at your release site?

Generalize - Why might it be useful to keep records?

Apply - Why do people like to keep diaries? How might you use a personal or wildlife diary 20 years from now?

Additional Information

Appendix G: *Site Selection Guidelines for Release of Galerucella Beetles*

Wetland Plant Diversity Sheet

Galerucella beetle release

Location: _____

Date: _____ Time: _____

Temperature: _____ Weather Conditions: _____

Evaluator(s): _____

Plant Diversity: _____

Species along the transects: (L - loosestrife, G - grass, C - cattail, O - other)

Transect 1 _____

Transect 2 _____

Transect 3 _____

Calculate the Diversity Index, DIG, for each transect:

Transect	1	2	3
DI_G			

Optional Calculations:

Transect	1	2	3
DI_M			
DI_S			
DI_E			
DI_O			

activity 10

Galerucella Beetle Release

Objectives

- Release your *Galerucella* beetles in a wetland infested with purple loosestrife.
- Establish the monitoring program to study the effects of the beetles on the wetland.

Setting up the Sampling Area

1.) Measure the plant diversity as described in Activity Three.

2.) Draw a map of the area. Provide enough detail so that you can find your release location the next time you survey the area even if someone removes your field markers. The survey work you completed in Activity Three will provide baseline information about the wetland area where we released the beetles. This can be done at the same time you release your beetles. You will be able to evaluate how well the population is doing by comparing future Diversity Index data.

Release Sampling

1.) Record the location, date, time, temperature and other weather conditions, and the name(s) of the evaluators at the top of the data sheet.

2.) Plant Data
Calculate and record the plant Diversity Index (or indices, if you prefer) as described in Activity 3.

3.) Release your beetles as described below. Keep the data that you took for comparisons to future data you collect.

Beetle Release

1.) Beetles should be released when new adults are visible and the potted purple loosestrife plants are nearly defoliated.

2.) Choose a release area with a thick growth of purple loosestrife that is in open sunlight.

3.) Move the entire plant and pot to the release site.

4.) Remove the mesh sleeve.

5.) Shake out any beetles still in the mesh bag (turn the mesh bag inside out).

6.) Remove the tomato cage and leave the potted root crown in place for one year. Record the spot of release on a map. Mark the location with 10' PVC pipe. Push the pipe into the wetland as far as you can.

Activity Eleven
Evaluating the Impact of *Galerucella* on Purple Loosestrife

Leader Summary Sheet

General Description

Students will do follow-up studies of the impact of the beetles on the population of purple loosestrife and the plant species diversity of the wetland.

Season

Spring - Summer

Estimated Time

2-3 hours

Materials

- See the Wetland Plant Diversity Survey, Activity Three (to review the equations)
- Biological Control of Purple Loosestrife Spring & Fall Sampling Sheets (provided at the end of this activity)

Reflect - Why is it important to go back to your release site and determine if the beetles you released have made any impact on the purple loosestrife infestation? Why might it take several years to see any impact against purple loosestrife?

Generalize - How can noting and reporting your impact be useful to the projects you work on?

Apply -How could you expand your efforts by reporting about your efforts to a local paper?

Photo: Pat Charlebois, Illinois-Indiana Sea Grant/Illinois Natural History Survey

Additional Information

It is important to return to evaluate your purple loosestrife biological control efforts. The most important reason is so that youth will see the positive results of all their work and realize that they can make an impact on the purple loosestrife problem. The follow-up study is an important part of any scientific study - it is very important to see how well your efforts worked to make improvements and changes for future work.

Note: Springtime sampling focuses on the beetles. Fall surveying focuses on the plants.

Notes

activity 11

Evaluating the Impact of *Galerucella* on Purple Loosestrife

Objectives

- Monitor the purple loosestrife and beetle populations in the wetland area where you released the beetles.
- Report on the success of biological control in your wetland area and predict the future impact.

Note: This activity must be completed after the beetles have had a chance to have an effect on the purple loosestrife. Please be aware that you may not see a decrease in the amount of the plant for two or three years.

Procedures

Using some of the same techniques as when you first released the beetles and collected data, your group will monitor the wetland area each spring and fall to determine the impact of *Galerucella* beetles on purple loosestrife in your release area.

Spring Sampling

Sampling in the spring should take place after the beetles have emerged from their over-wintering locations and resumed normal activity. At this time the loosestrife plants will be one to two feet tall. (If plants are more than three feet tall, it will be difficult to find the beetles or their damage.) In the Midwest this is likely to occur in the second half of May.

1.) Record the location, date, time, temperature and other weather conditions, and the name(s) of the evaluators at the top of the data sheet.

2.) Approach the sample area slowly to avoid disturbing any adult beetles.

   a.) Count and record the number of adults you see in a one-minute interval. Note that adults may be found anywhere on the plant but will most often be found feeding at the shoot tip.

   b.) Count and record the number of larvae you see in a one-minute interval. Note that larvae may be found anywhere on the plant.

   c.) Count and record the number of eggs you see in a one-minute interval. Note that eggs may be found anywhere on the plant, including the undersides of leaves.

Fall Sampling

Fall data collection occurs after plants have matured. The *Galerucella* beetles are not active in the fall; so all data collected involve only the purple loosestrife plants.

Plant Data

a.) Record the location, date, time, temperature and other weather conditions, and the name(s) of the evaluators at the top of the data sheet.

b.) Calculate and record the plant Diversity Index (or indices) as described in Activities 3 & 10.

c.) Measure and record the height of the five tallest loosestrife stems along each transect (from root crown to tip of plant).

d.) For each stem you measured, count and record the number of inflorescences. The inflorescence is the part of the stem containing flower buds.

e.) For each stem you measured, measure and record the length (inches) of the five upper inflorescences.

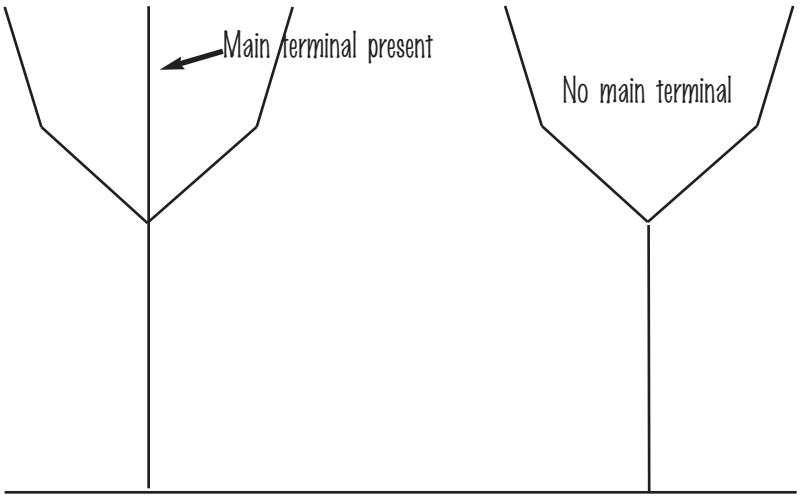
f.) Record if the main terminal is present or not (see picture).

Data Analysis

1.) Prepare graphs that compare the data you've collected on your data sheets.

2.) Write a short essay about the success of your biological control efforts at the wetland. Predict the future impact of the *Galerucella* beetle on the purple loosestrife in the wetland. How will the wetland area change in one year? Five years? Ten years?

3.) You may want to contact your local newspaper to see if they would print your group's report on the biological control of purple loosestrife.



Biological Control of Purple Loosestrife

Fall Sampling Sheet

Location:_____

Date:_____ Time: _____

Temperature:_____ Weather Conditions:_____

Evaluator(s): _____

Plant Diversity:_____

Species along the transects: (L - loosestrife, G - grass, C - cattail, O - other)

Transect 1 _____

Transect 2 _____

Transect 3 _____

Calculate the Diversity Index, DIG, for each transect:

Transect	1	2	3
DI_G			

Optional Calculations:

Transect	1	2	3
DI_M			
DI_S			
DI_E			
DI_O			

Additional plant information:

Transect	1	2	3
Height of 5 tallest stems			
Number of inflorescences on the 5 tallest stems			
Length of each of the 5 inflorescences you measured			
Number of main terminals present on the 5 tallest stems (0-5)			

Biological Control of Purple Loosestrife

Spring Sampling Sheet

Location: _____

Date: _____

Time: _____

Temperature: _____

Weather Conditions: _____

Evaluator(s): _____

Beetle Information:

Number of *Galerucella* beetles counted in five minutes: _____

Number of *Galerucella* beetle larvae counted in five minutes: _____

Number of *Galerucella* beetle eggs counted in five minutes: _____

Appendix A
Removing Purple Loosestrife by Hand

Adapted from "A universal manual for purple loosestrife control." C. Keddy. Ontario Federation of Anglers and Hunters (O.F.A.H.), 1993.

Sometimes digging and pulling purple loosestrife is the best method of control. The Ontario Federation of Anglers and Hunters (O.F.A.H) has several years experience with hand removal of purple loosestrife. A synopsis of their experiences is given here.

Pulling plants out of the ground by hand is most effective in eliminating young (1 - to 2 - year-old) plants. Young plants can be distinguished as follows: both the current flowering shoot and the remains of the first-year flowering shoot will be attached to the crown of 2-year old plants, while only the current flowering stalk will be present on one year old plants. The flowering stalks of older plants tend to pull loose from the well-established root crown that will flower in subsequent seasons. This shoot removal, however, does eliminate seed production for the season.

Hand pulling is easiest and most effective when the soil is wet (e.g. after a rain, when water levels are high). All the stalks arising from a single root crown should be grasped firmly near the base with both hands and pulled evenly and slowly to avoid detachment from the crown. Gently rocking the stem back and forth while pulling may also help.

Flowering plants should either be dried and burned, or put in garbage bags and disposed of where there is no chance of the seeds or fragments establishing. Prior to flowering, pulled plants may be safely dried in open sunny areas where there is no chance of plants rooting or washing away.

Digging plants up helps to ensure that a sufficient portion of the root system was removed to prevent resprouting, but digging also disturbs the soil significantly. If herbicides cannot be used and hand pulling did not remove the root crown, digging would be appropriate for isolated plants and low-density infestations. Garden forks can be used for loosening large root crowns prior to hand pulling.

Hand pulling is labor intensive. The O.F.A.H. "Project Purple" workers found hand-pulling rates could vary between 400 and 3,000 plants/worker-day, depending upon the age and density of the plant and the moisture content of the soil. After one year of hand pulling in Presquile Provincial Park, there were no seedling clusters obviously associated with places from which the plant had been pulled and, despite the variance in age of the plants (root crowns could not be completely removed in all cases), there was a great reduction in the number of plants the year following pulling.

The advantages of this technique are that potentially harmful herbicides are not added to the environment and it is effective on young plants (less than 2 years). It is also a technique that volunteers can easily employ, The drawbacks of this method are that soil surface disturbance may promote further purple loosestrife seed germination or the establishment of other alien plant species, the micro topography (possible affecting seed germination of desirable species) is altered, effectiveness varies with plant age, plants pulled must be removed to prevent establishment from fragments, and it is very labor intensive.

Appendix B
Purple Loosestrife Control Options

How does one know which control method is best? Is the best solution snipping the seed heads, burning, spraying, pulling, digging, or a combination of these? The answer really depends on local circumstances.

New or Localized Infestations

In habitats where just a few isolated plants exist or the infestation is localized in a very small area (less than one acre), it is best to dig them up. Be sure to get all the roots, but try not to overly disturb the surrounding soil or vegetation. Plant cover is vital to keep loosestrife from reinvading. All plant material should be dried and burned, or placed in a closed black plastic bag in the sun for several days where the high heat will kill the plant and seeds. Any plant materials left in the field can easily sprout again. See Appendix A to learn more about removing loosestrife by hand.

Where permitted, plants may be treated with an approved herbicide. Rodeo© is an effective herbicide registered for use in wetland habitats. However, it is nonselective and will kill most vegetation it contacts. Spot sprays directed at the early flowering stage of purple loosestrife are most effective. Broadcast sprays are not recommended.

Cutting of plants can be used as a holding action until other measures can be taken. Flowering stalks can be cut to prevent seed formation, and old flower heads should be removed because they may still contain viable seed.

Established Infestations

Where hundreds of mature plants exist, or the infestation is spread over several acres, digging may be impractical. The use of herbicides and cutting are still options to consider. In established infestations where millions of purple loosestrife seeds are present in the soil, care must be taken not to spread them on muddy boots or equipment. Disturbance of the soil and vegetation should be minimized so as not to open up new areas for loosestrife seedling establishment.

Use the Purple Loosestrife Identification card (Appendix K) to learn to recognize purple loosestrife throughout the year. Sketch a map to record areas where you see vegetative growth in the spring, the flowering plants in late summer, or the dry, erect stems in the winter. Plan ahead. In most instances where more than 500 mature plants occur, biological control is likely to be the only practical long-term management option.

Photo by David Voegtlin, Illinois Natural History Survey

Appendix C

Natural Enemies to Control Purple Loosestrife

In nature, all organisms live in a dynamic balance with the other organisms in their environment. Population levels rise and fall over time, but typically revert to a long-term level that can be supported by the habitat. The maintenance of this dynamic balance is a fundamental part of the ecology of natural systems and helps to preserve their integrity and function. For example, while the rabbit population may temporarily expand to the detriment of a flower or vegetable garden, eventually the local foxes, owls, and cats take their individual toll, reducing the rabbit population back to a level typical for the neighborhood. If this did not occur, rabbit disease or starvation would likely ensue, accomplishing a similar result. This process of natural control is often referred to as the "balance of nature. " Primary actors in this play are the "natural enemies:" predators, parasites, and diseases, that every organism has evolved with and which serve to help keep its population in check.

Occasionally, something occurs to disrupt these natural controls. The presence of an overgrown field may provide the rabbits increased protection from predators. An excellent food source may increase their general health and allow them to better resist some common diseases. However, as long as all the natural enemies are still present, eventually a balance will be restored. But what would happen if the natural enemies were to suddenly disappear altogether? In a sense, this is what happened when purple loosestrife arrived in North America. Because of human activity, purple loosestrife arrived here without its natural enemies. It is now an established nonindigenous aquatic nuisance species.

In Europe, purple loosestrife is a native plant and lives in balance with the other plants and animals that share its wetland habitat. While it is a part of wetland ecosystems, it never becomes the dominant component as it does here in North America. This is because in its native home, purple loosestrife is attacked by many natural enemies that keep its population in check. Over 120 insects and several diseases have been documented to attack purple loosestrife. Insects are probably the most important natural controls of purple loosestrife. When a purple loosestrife population rises in a wetland, these insects soon find it. Some insects feed on the flower buds and developing seeds, reducing seed production. Other insects feed on the leaves, killing the tips of the plant and stunting it while reducing the amount of photosynthetic energy it can produce. Finally, others tunnel into the root system, weakening it and eventually killing the plant.

Partly because of its long evolutionary battle with these natural enemies, purple loosestrife has developed some impressive characteristics of its own. As a perennial plant it is able to persist in the same location for many years, storing energy in its root system in one season that is then used for growth in the following spring. Using these reserves, loosestrife can grow very rapidly, shading out slower-growing plants nearby. It is a very tall plant producing multiple stems from each root crown. Stems can often exceed seven feet in height and produce multiple flowering stalks. If a stem should happen to break off, it can easily sprout roots and establish a new plant. In addition to this vegetative reproduction, loosestrife is also a prolific producer of seed. One mature loosestrife plant can produce over 2.5 million seeds per year. These tiny seeds can float on the water, blow across frozen marshes, or even be carried on the fur or feathers of wetland animals to some distant location. It is these traits that make purple loosestrife such a threat to wetland biodiversity in North America.

Without natural enemies, North American loosestrife populations can expand unchecked to the point that they frequently dominate individual wetlands. As native plants are crowded out, other organisms that depend on them disappear as well. For example, in some marshes cattail has been replaced by a solid (monotypic) stand of loosestrife. Muskrats, which depend on cattail but do not eat loosestrife, are soon displaced as well. As importantly, the role that muskrats formerly played in the marsh's ecology is lost. For example, muskrat houses are no longer available as nesting platforms for geese. In addition, the mosaic of cattail and open water created by muskrat feeding, and the resulting habitat that is favored by many types of waterfowl, is replaced by solid stands of loosestrife.

Scientists know that in its native range, purple loosestrife is a part of wetland ecosystems, but never becomes the dominant vegetation. By careful study, they found several species of insects that feed only on purple loosestrife and are largely responsible for keeping its population in balance. The process of identifying, studying, and importing these natural enemies is known as importation biological control. Biological control refers to the process of using a pest's natural enemies to reduce its density and the damage that it causes. These natural enemies may be predators, parasites, or pathogens. Most people are familiar with the use of predators such as lady beetles to help control insect pests in a garden. Fewer are aware that biological control can also be used to help manage wetland plants like purple loosestrife.

Biological control has been practiced in the U.S. for over 100 years. Most of the effort has gone into the control of insect pests. Farmers in the Midwest and Great Plains are very familiar with the highly successful control of two exotic insect pests, the cereal leaf beetle and the alfalfa weevil, using parasites imported from Europe. The alfalfa weevil project is estimated to save U.S. agricultural producers $10 million every year in reduced pesticide usage and increased yields. Because these natural enemies are self-sustaining, these benefits will continue long into the future. Control of Klamath weed, a European plant that invades rangelands in the western U.S., was also highly successful in just a few years. In other cases, natural enemies have failed to establish or never built-up to sufficient numbers to impact the pest. Fortunately, in the case of purple loosestrife, some of these hurdles have already been overcome, and the prospects for successful control are quite good.

Three species of plant-feeding beetles, *Galerucella calmariensis*, *Galerucella pusilla* and *Hylobius transversovittatus*, show the greatest promise as biological controls for purple loosestrife. The *Galerucella* leaf beetles feed on bud, leaf, and stem tissue and cause defoliation and prevention of flowering and seed production. Continued defoliation leads to plant death. *Hylobius* (weevils) larvae mine in root tissue, weakening and ultimately killing the plant. These insects have undergone extensive testing to determine their safety and effectiveness, receiving USDA approval in 1992. Results of 1996 releases of *Hylobius* are still uncertain, with most experts estimating that 5-15 years maybe required for the full impact of these beetles to be realized. *Hylobius* is also more difficult to raise than *Galerucella*.

Galerucella is being used to do most of the biological control of purple loosestrife in North America because it can begin to impact purple loosestrife infestations in as little as two or three years and it is relatively easy to raise.

Because they are host-specific, the number of *Galerucella* beetles in any inoculated area will rise and fall based on the amount of purple loosestrife present. At first, with an almost unlimited food supply, many beetles will be produced until their biotic potential is reached. As purple loosestrife density declines, the beetles will have a harder time finding food, so they will produce fewer offspring and their population will decline. Over time a balance will be reached as purple loosestrife and its natural enemies reach a stable relationship. Biological control experts do not expect *Galerucella* beetles to totally eliminate purple loosestrife but, rather, it is hoped they may be able to reduce its density by about 90%. And, once established, the beetles will continue to control loosestrife on a long-term, self-sustaining basis.

Appendix D
Raising *Galerucella* Beetles Indoors

The following is a stepwise procedure for the indoor rearing and subsequent release of *Galerucella* spp. beetles for biological control of purple loosestrife (*Lythrum salicaria*).

Overview

Using this procedure, purple loosestrife root crowns will be potted and placed in a tray with water. Each pot will have a tomato cage placed into it and a fine mesh bag that serves as a cage pulled over the top. After 4 to 6 weeks of plant growth, place 20-25 *Galerucella* beetle adults into the cage. The beetles will produce another generation, with the new adults ready in about 6 to 8 weeks. With this setup, it is expected that 500 to 1,500 new beetles per pot will be produced in the second generation.

A fairly typical timeline for rearing and release of *Galerucella* beetles follows:

Event	Approximate Dates
Pot root crowns	Feb. 15 to March 1
Place beetles into cages	March 15 to April 1
Release beetles into wetland	May 1 to May 15

Getting Started

The first step is to assemble the materials necessary for the rearing process. A list of supplies needed for the beetle rearing kit and their approximate cost is in the box above.

You will be able to purchase all of your supplies from a local garden center or nursery (consider asking for donated materials) except, perhaps, for the sleeve cage. You can create your own with two yards of fine mesh fabric and drawstrings (see Activity 8, B3 & notes). Your cost will vary depending on where materials are purchased and whether you are able to substitute used for new materials.

Collecting Purple Loosestrife Root crowns

Prior to growing plants, purple loosestrife root crowns must be collected. The root crown is the underground portion of the plant that survives the winter. It consists of hard, woody storage roots and stem buds, which arise from them. Root crowns are used to establish plants rather than establishing from seed because the root crowns will produce multiple, hardy stems in less time and with less effort.

Indoor Beetle Rearing Kit

Item	Cost	Quantity
Wire tomato cage (42")	$2.50	1 each
Potting mix, non-soil type (20qt.)	$5.00	1 each
Osmocote™ (or similar) slow release fertilizer (14-14-14 NPK)	$6.00	1 T.
Four gallon pot	$6.00	1 each
Bottom tray	$4.00	1 each
Fine mesh sleeve & drawstring (twine, rubberband, etc.)	$10.00	1 each
Pole marker (PVC pipe)	$5.00	10 ft.

Root crowns may be collected in the late fall after purple loosestrife top growth has died, or early in the spring, prior to new growth, Collect root crowns from mature stands of purple loosestrife that are at least two years old. Mature stands have larger root crowns that contain more stored energy for plant growth.

Locate groups of dead stems from the most recent year's growth and dig around these "clumps" to dislodge them from the soil. A tile spade, one with a long, narrow blade, works well for this type of digging, but any spade will work. Use the spade to break apart large root crowns into sizes that will fit into the pots being used. The root crowns will be roughly eight inches in diameter. Using the spade, knock away loose soil from the root crowns and cut away all but about six inches of the dead stem top growth. It is not necessary to clean all soil and debris from the root crowns. Live, healthy root crowns have a tan to brown color, are pink to whitish on the inside, and are somewhat flexible. Root crowns that are dead will be charcoal-black in appearance and brittle. Sometimes stem buds can be found sprouting from the root crowns, ensuring a healthy root crown has been chosen.

Root crowns collected in the spring may be potted immediately, or stored outdoors for a short time. Keep the root crowns moist until ready for planting. Collection of root crowns will need to take place at least 12 weeks before the date you plan to release new beetles. Fall-collected root crowns may be stored outdoors. If collecting in the fall, gather twice as many root crowns as you will need in order to compensate for winter-kill and other factors that can damage the root crowns. Moisten the pile, then cover it with a tarp to keep root crowns moist and out of light. Do not cover with straw, as this attracts nesting animals that may feed on the root crowns during the winter months.

Potting the Root Crowns

Fill the four-gallon pots halfway with potting mix and sprinkle in one tablespoon of fertilizer. A slow-release fertilizer will gradually provide the plants with needed nutrients. Place one large, or several smaller, root crowns into the center of each pot and fill the remainder with potting mix. Pot the root crowns oriented in the same direction they were growing in the wetland, with the stems directed upwards. It is a good idea to set up an extra pot or two to ensure that you have at least one healthy plant to provide to the beetles. Cover the root crowns with potting mix. Ideally each pot will have six or more healthy stems. *Do not press the potting mix into the pot.* The beetle larvae move into the top inch of the soil to pupate, and this soil should remain loose.

Put the potted plant into the bottom tray. Make certain that the pot has holes in the bottom to allow water uptake. For the initial wetting of the potting soil, water the tops of the pots to settle the soil around the root crowns. Add more potting soil if needed. After this initial wetting, water plants by filling the bottom tray *only*. The bottom tray should always have water in it.

Place a tomato cage into the pot, pushing it all the way to the bottom. As the stems grow, direct them into the center ring of the tomato cage. Later, you will pull a sleeve cage over the tomato cage. Leave the sleeve off for now, until the plant is at least 12 inches tall. This will maximize the amount of light reaching the plant.

Plant Placement

Place the potted plants where they will receive the most sunlight, preferably in a south-facing window. Use a greenhouse if one is available. A grow light may be a necessary addition where sunlight is minimal. Temperatures between 75 and 85 degrees Fahrenheit are ideal for the plants and beetles. Consider the use of a heat lamp if your room is too cold.

Maintaining the Plant

Make sure that the plants have adequate water at all times. After the initial wetting of the potting soil, water plants by filling the bottom tray only. Do not water the top of the pots again, as this may cause a crust to form on the potting soil surface, which could interfere with pupation. As the plants grow larger they will require daily watering.

When stems are about 12 inches tall pinch off about half an inch of the tip of each stem (apical meristem) to stimulate lateral shoot development. This will produce a bushier plant with lots of preferred larval feeding sites. One to two weeks after pruning, the plants should be ready to receive the *Galerucella* beetles.

Choose the healthiest looking plants to infest with the beetles. Wrap tape around the welds on the tomato cage to protect the sleeve from tearing as it is pulled over the tomato cage. Use string or a rubber band to tie off the top of the sleeve. Slide the sleeve over the tomato cage and down onto the upper lip of the pot. Most pots have a groove along the upper lip that works well to hold the drawstring in place. Secure a drawstring tight around the pot or tape the bottom edge of the sleeve to the pot with duct tape. It is very important to have a tight fit between the cage and the pot.

Infesting Purple Loosestrife with Beetles

Whether you collect your beetles from a field site or receive them through mail order, place them promptly onto your plants. Keep the shipping container that holds the beetles out of direct sunlight until ready to add them to the plants. *Do not expose beetles to temperature or humidity extremes while in the shipping container.* Be sure to put the beetles on your plant the day you receive them.

Open the top of the sleeve cage; shake the beetles out of the container and into the cage. Securely close the cage top. Check that the bottom of the sleeve is tight against the pot. If the drawstring does not fit securely against the pot use a large rubber band or heavy tape to secure it. The sleeve must be secured to prevent it from slipping down away from the pot, which would allow beetles and larvae to escape, or predators to enter the cage. Periodically check that the bottom of the sleeve is secured tightly against the pot.

Galerucella Development

The *Galerucella* beetle adults will begin to feed on the foliage of the plant soon after you place them in the cage. Holes in leaves are an indication of adult feeding. Males and females will begin mating soon after feeding. It may take up to two weeks before the females begin to lay eggs. The eggs are laid in small groups on stems and leaves. They are round, pinhead-sized and white to cream-colored with a thin black, stringy deposit across the top of each mass. The black material is excrement that the female deposits. Egg masses are small (0.5-1 mm diameter) and can be very difficult to see through the screen, but keep looking carefully and you will eventually become quite good at spotting them. Females lay eggs for several weeks.

Eggs hatch within two weeks. Larvae are yellow to orange and have black stripes across the width of the body. The larvae have three growth stages, called instars. The first two instars are very small and feed concealed in the growing points of the plant. You will probably not see them, but damage to the tips of stems will be noticeable. Third instar larvae are larger and more easily seen. Full-grown larvae are about 1/4 inch long. The first indication that late second and third instar larvae are present will be a characteristic type of leaf feeding. The larger larvae eat the upper layer of the leaf, leaving the lower layer behind. This "window-pane" look of the leaves occurs near the top of the plant first and progresses downward over the entire plant. Fine, dust-like, black excrement (frass) collecting on upper leaf surfaces or sleeve cage folds is another indication of feeding activity.

The larvae take about three weeks to become full-grown. Last instar larvae crawl to the soil and burrow just under the surface where they change into a pupa. This is the growth stage between the larva and the adult. Pupae do not feed and are not mobile. The pupal stage lasts about two weeks, after which the new adult beetles crawl out of the soil and begin to look for food. The diagram in Activity Nine shows approximate development times for each life stage. These are highly variable, depending on temperature and food quality.

The newly emerged adults gather at the top of the sleeve cage. These new beetles are lighter colored than the older beetles that were originally placed on the plants. The combination of extensive

defoliation, new beetles at the top of the cage, and few larvae remaining on the plant indicate that the beetles are ready for release into a wetland. From the time that beetles are put into the cages to the time that the new generation of beetles emerge will be from six to eight weeks. Do not wait for all of the new beetle adults to emerge. In most cases, the larvae will heavily defoliate the plant and there will not be enough food to sustain the adults for very long. If the plant is completely stripped of its foliage and many larvae (more than 50) are still present, it may be necessary to supplement feeding with purple loosestrife from your extra plant or foliage collected from a wetland. If collecting from a wetland, be sure that the foliage has not been treated with any insecticide (against mosquitoes, for example). Place the freshly cut shoots in a container of water and place in contact with the stripped plants. Larvae will move to the new shoots to feed.

Next Steps

You may choose to make a wetland release of your small colony or to raise another generation of *Galerucella* beetles outdoors (see Appendix E). If you decide to release your first generation of beetles, take the entire pot with tomato cage and sleeve cage to the release site. It may be difficult to transport the potted plant intact in the pot due to limited vehicle space. In this case, loosen the sleeve cage from around the pot and cut the stems off just above the soil line. Pull the tomato cage out of the soil and cover the legs of the cage with tape to prevent them from ripping the sleeve, and pull the drawstring closed at the bottom of the cage. Cover the pot with a cloth, garbage bag, etc. and secure it around the pot with string or tape. Take the cage with plants inside and the pot to the release area.

Choose a release site that is not readily visible to vandals who may disturb the pot or release area. Also, beetles prefer areas that receive full sunshine, so avoid areas that will be shaded for a long period each day. Place the potted plant with the sleeve still in place next to purple loosestrife plants already growing in the release area. Set the pot on the ground where it will remain upright so that the unemerged insects in the soil will be able to safely complete development. Remove the sleeve and tomato cage from the pot. Invert the sleeve cage and shake the beetles off of it. If there are larvae inside of the cage, gently place them onto purple loosestrife plants. Beetles and remaining larvae will move to new plants to continue feeding and development. Leave the intact pot, plant and soil behind.

Record the exact location of the release site with a diagram and with measurements from permanent landmarks (trees, docks, etc.). It is very important to have multiple means of relocating the release site since vandals; seven-foot-tall loosestrife, ice or heavy snow can easily remove or obscure other markers you will place. Use PVC pipe to mark the release area. A 10-foot length of PVC pipe can usually be sunk two to four feet into the wetland. This will ensure that the same spot may be located in the fall and in subsequent years to monitor the progress of your release.

Appendix E
Outdoor Rearing of *Galerucella* Beetles

The following pages give a stepwise procedure for the outdoor rearing and release of *Galerucella* spp. beetles for biological control of purple loosestrife (Lythrum salicaria).

Overview

The following instructions are for 8 to 10 purple loosestrife rootcrowns to be potted and placed in a children's wading pool with water. It is best if each 4-Her has a plant to pot and monitor. Each pot will have a tomato cage placed into it and a fine mesh bag that serves as a cage pulled over the top. After 4 to 6 weeks of plant growth, you will place approximately 25 *Galerucella* beetle adults in each cage. Six to eight weeks later 500 to 1,500 new beetles will be produced from each pot. With 10 pots in each wading pool, 5,000 to 15,000 or more adult beetles will be produced for release into a purple loosestrife-infested wetland.

A typical timeline for rearing and release of *Galerucella* beetles is given below. Your dates will vary depending on your location and weather. (Dates given are for the Midwest.)

Event	Approximate Date
Pot rootcrowns	April 5-30
Place beetles into cages	May 10-30
Release beetles into wetland	June 30-August 1

Outdoor Beetle Rearing Kit

Item	Cost	Quantity
Wading pool (6 ft. diameter)	$15.00	1
Wire tomato cage (42")	$2.50	1 each
Potting mix, non-soil type (20qt.)	$5.00	1 each
Osmocote™ (or similar) slow release fertilizer (14-14-14 NPK)	$6.00	1T.
Four gallon pot	$6.00	1 each
Twine, twist ties, or large rubber band	$1.50	1 each
Fine mesh sleeve	$10.00	1 each
Aspirator (if desired - to remove beetles from the plants)	$15.00	1
PVC pipe (10 ft.)	$5.00	1 each

Getting Started

The first step will be to assemble the materials necessary for the rearing process. A list of supplies needed for the beetle rearing kit and their approximate cost is listed in the box below.

Suppliers

You may be able to purchase all of your supplies from a local garden center or nursery (they might even donate materials). Or, you may wish to order your supplies. Costs can vary considerably depending on the supplier. Be sure to call suppliers for current pricing, ordering restrictions, and shipping costs. Some suppliers have minimum purchase orders.

Collecting Purple Loosestrife Rootcrowns

Before you grow the plants, purple loosestrife rootcrowns must be collected. The rootcrown is the portion of the plant that survives the winter. It consists of hard, woody storage roots and stem buds that arise from them. Rootcrowns are used to establish plants rather than establishing from seed because the rootcrowns will produce multiple, hardy stems in much less time and with less effort.

Root crowns may be collected in the late fall after purple loosestrife topgrowth has died, or early in the spring prior to new growth. Leave the rootcrowns outside so they don't begin to grow. Collect from mature stands of purple loosestrife that are two years or more old. Mature stands have larger rootcrowns that contain more stored energy for plant growth.

Locate groups of dead stems from the most recent year's growth and dig around these "clumps" to dislodge them from the soil. A tile spade, one with a long, narrow blade, works well for this type of digging, but any spade will work. Use the spade to break apart large rootcrowns into sizes that will fit into the pots being used. These will be roughly eight inches in diameter. Using the spade, knock away loose soil from the rootcrowns and cut away all but about six inches of the dead stem topgrowth. It is not necessary to clean all soil and debris from the rootcrowns. Live, healthy rootcrowns are tan to brown on the outside and are pink to whitish on the inside and are somewhat flexible. Rootcrowns that are dead will be charcoal-black and brittle. Sometimes buds can be found sprouting from the rootcrowns, ensuring a healthy rootcrown has been chosen.

Root crowns collected in the spring may be potted immediately, or stored outdoors for a short time. Keep the rootcrowns moist until ready for planting. Fall-collected rootcrowns may be stored outdoors. If collecting in the fall, gather twice as many rootcrowns as you will need in order to compensate for winterkill and other factors that can damage the rootcrowns. Moisten the pile, then cover it with a tarp to help keep rootcrowns moist and out of the light. Do not cover with straw, as this attracts nesting animals that may feed on the rootcrowns during the winter months.

Potting the Rootcrowns

Although you will be placing 8 to 10 pots into each wading pool, it is a good idea to prepare as many as 15 pots so you have extras in case some rootcrowns don't grow. Fill the 15 plastic four-gallon pots halfway with potting mix and sprinkle one tablespoon of fertilizer into each pot. This is a slow-release fertilizer that will gradually provide the plants with needed nutrients. Place a rootcrown into the center of each pot and fill the remainder with potting mix.

Pot the root crowns oriented in the same direction they were growing in the wetland, i.e., stems directed upwards and cover with potting soil. Multiple stems will grow from each rootcrown. Ideally, the rootcrown put into each pot will result in six or more healthy stems per pot. Several smaller rootcrowns can be combined within a pot to produce this number of stems. *Do not press the potting mix into the pot.* (The beetle larvae move into the top inch of the soil to pupate and this region should remain loose.)

For the initial wetting of the potting soil, water the tops of the five minutes:pots to settle the soil around the rootcrowns. Add more potting media to pots that need it. The soil line should be within an inch of the top of the pots. After this initial soaking, water plants by filling the pool only. Label each pot if the 4Hers want to keep track of their plant.

Place a tomato cage into each pot, pushing it all the way to the bottom. Wrap tape around the welds on each tomato cage to protect the sleeve cage from tearing. Use string or a rubber band to tie off the end of the sleeve that has no drawstring, this is the top. Slide a sleeve (see Activity, B3 & notes) over the tomato cage and down onto the upper lip of the pot. Most pots will have a groove

along the upper lip, that works well to hold the drawstring in place. Place the drawstring in the groove and pull it tight around the pot. It is very important to have a tight fit between the cage and the pot. Putting the sleeve cage on at this point is important to help keep aphids and predators from infesting the plants prior to beetle rearing. At any point prior to receiving beetles, you may exchange a healthy plant for one that is not growing vigorously.

Place the wading pool outdoors on level ground in an area that gets full sunlight. Do not place the pool in an area where air movement is greatly restricted. Evenly space the pots within the pool to allow air to move freely between the cages. Put potted plants into the wading pool and add water to the pool. *Do not water the top of the pots again*, as this may cause a crust to form on the potting soil surface, disrupting larval movement and pupation in the soil.

Pots should be supported to remain upright in a wind when the plants become taller. The tops of the sleeve cages can be tied to any handy overhead support such as a clothesline. Alternatively, drive four fence posts into the soil in a square pattern around the pool. Tie heavy string or light wire to the posts and connect them in an X pattern. Use string or a clothespin to attach the top of each sleeve cage to one of the lines to provide support.

Maintaining the Plants

Make sure that plants have adequate water at all times. Keep about three inches of water in the pool. Too much water gives the pots enough buoyancy to easily tip over. An overflow hole should be cut into the side the pool 5 inches from the bottom to prevent tip-overs when heavy rainfalls occur. Periodically check that each sleeve cage is secured tightly around each pot.

When plants reach about 12 inches in height, pinch off about half an inch of the tip of each stem (apical meristems) to stimulate lateral shoot development. This will produce a bushier plant with lots of preferred larval feeding sites. One or two weeks after pruning, the plants should be ready to receive *Galerucella* beetles.

Infesting Plants with Beetles

When you receive your *Galerucella* beetle adults they must be promptly placed onto plants. Keep the shipping container that holds the beetles out of direct sunlight until ready to infest plants. Do not expose beetles to temperature or humidity extremes while in the shipping container.

Untie the string at the top of the sleeve cage you want to infest with beetles and shake them onto the plant. Securely close the cage top. Repeat for each pot. The beetles are very good at "hiding," so half or fewer of the beetles will be readily visible on the plants. Extra beetles may be divided among the pots or placed on your extra plants.

Be sure to secure the drawstring at the bottom of the sleeve cage tightly against the pot. If the drawstring does not fit securely against the pot, use a large rubber band or heavy tape to secure it. The sleeve cage must be secured to prevent it from slipping down away from the pot, which would allow beetles and larvae to escape, or predators to enter the cage. Periodically check that the bottoms of the sleeve cages are secured tightly against the pots.

Galerucella Development

The *Galerucella* beetle adults will begin to feed on the foliage of the plants soon after you place them in the cages. (Holes in leaves are an indication of adult feeding.) Males and females will begin mating soon after feeding. It may take up to two weeks before the females begin to lay eggs. The eggs are laid in small groups and may be attached to stems and leaves. They are round, pinhead-sized and white to cream-colored with a thin black, stringy deposit across the top of each mass. The black material is excrement that the female deposits. Females lay eggs for several weeks. Eggs can be very difficult to see through the screen, but keep looking carefully and you will eventually become quite good at spotting them.

Eggs hatch within two weeks. Larvae are yellow to orange and have black stripes across the width of the body. The larvae have three growth stages, called instars. The first two instars are very small and will probably not be noticeable through the sleeve cage. Third instar larvae are larger and more easily seen. Full-grown larvae are about 1/4 inch long. The first indication that larvae are present will be a characteristic type of leaf feeding. Larvae eat the upper layer of the leaf, leaving the lower layer behind. This "window-paning" of the leaves usually occurs near the top of the

plant first and progresses downward over the entire plant. Fine, black, dust-like excrement (frass) collecting on leaf surfaces or sleeve cage folds is another indication of feeding activity.

The larvae take about three weeks to become full-grown. Last instar larvae crawl to the soil and burrow just under the surface, where they change into a pupa. This is the growth stage between the larva and the adult. Pupae do not feed and are not mobile. The pupal stage lasts about two weeks, after which the new adult beetles crawl out of the soil and begin to look for food. The length of time in each stage is highly variable, depending on temperatures and food-quality.

The newly emerged adults gather at the top of the sleeve cage. These new beetles are lighter colored than the older beetles that were originally placed on the plants. The combination of extensive defoliation, new beetles at the top of the cage, and few larvae remaining on the plant indicate that the beetles are ready for release into a wetland. It will be six to eight weeks from the time that beetles are put into the cages to the time that the new generation of beetles are ready to be released into a wetland. Do not wait for all of the new beetle adults to emerge. In most cases the larvae will heavily defoliate plants and there will not be enough food to sustain the adults for very long. If a plant is completely stripped of its foliage, and many larvae (more than 50) are still found on the plant, it may be necessary to supplement feeding with purple loosestrife shoots from another pot or foliage collected from a wetland. If collecting from a wetland, be sure that the foliage has not been treated with any insecticide (against mosquitoes, for example). Place the freshly cut shoots in a container of water and place in contact with the stripped plants. Larvae will move to the new shoots to feed.

Making the Release

Unless a pickup truck or van is available, it may be difficult to transport the potted plants intact with tomato and sleeve cages due to vehicle space restrictions. In this case, loosen the sleeve cage and cut the stems just above the soil line. Pull the tomato cage out of the soil mix and cover the legs of each tomato cage with tape to prevent them from ripping the sleeve and pull the drawstring closed at the bottom of the cage. Cover the pot with a cloth, garbage bag, etc., and secure it around the pot with string or tape. Immediately take the cages and pots to the release area. Do not leave the beetles inside of a vehicle for a prolonged period.

Within each release site, choose a location that is not readily visible to vandals who may disturb the pots or release area. Also, beetles prefer areas that receive full sunshine, so avoid areas that will be shaded for a long period each day. Place potted plants with the sleeve cage still in place next to purple loosestrife plants already growing in the release area. Space the pots around an area of about 33' by 33' (10m x 10m). Set the potted plants on the ground where they will remain upright so that the unemerged insects in the pots will be able to safely complete development and emerge. Remove the sleeve and tomato cage from the pot. Invert the sleeve cage and shake the beetles off of it. If there are larvae inside of the cages, gently place them onto purple loosestrife plants. The beetles and remaining larvae will move to new plants to continue feeding and development. Leave the pot, plant, and soil intact for several weeks, until all of the adults have had time to emerge. Empty soil from and collect the pots at a later date. Remove the rootcrown from the wetland to ensure that it does not begin growing. Leaving it where it can dry out completely may destroy the rootcrown.

Use PVC pipe to mark the four corners of the release area. A 10-foot length of PVC pipe can be sunk two to four feet into the ground. Use a permanent marker to label each PVC pipe with the direction of the corner represented, e.g., NE, SW, etc. to help you locate all four corners of the release area when the wetland vegetation becomes taller and more dense. This will ensure that the same spot may be located in the fall and in subsequent years to monitor the progress of your release. In addition, record the exact location of the release site with a diagram and with measurements from permanent landmarks (trees, docks, etc.). It is very important to have multiple means of relocating the release site since seven-foot-tall loosestrife, ice, or heavy snow can easily remove or obscure other markers you will place.

Appendix F

Life History and Ecology of *G. calmariensis* and *G. pusilla*

Purple loosestrife (*Lythrum salicaria*) is an exotic wetland perennial first noted in the U.S. in 1814. Since its arrival, purple loosestrife has established itself over a broad area in the U.S. and Canada. Due to the fact that it grows in nearly any moist environment and may produce up to 2.5 million seeds per plant, dense stands of purple loosestrife can become dominant in infested wetlands. Purple loosestrife damages wetland ecosystems by displacing native wetland flora and fauna. In an effort to bring this plant's population into a more stable balance, a program of biological control has introduced several natural enemies of purple loosestrife into the U.S. and Canada. Among these is a root-mining weevil, *Hylobius transversovittatus* that feeds specifically on purple loosestrife, and two leaf-feeding beetles, *Galerucella calmariensis* and *G. pusilla*.

Galerucella spp. are members of the leaf beetle family (*Chrysomelidae*). There are approximately 25,000 known species of leaf beetles worldwide, with 1,460 known species of chrysomelids in North America. Chrysomelid adults feed on foliage and flowering parts; while the larvae eat foliage or mine leaves, although others mine roots and stems. Some leaf beetles are serious agricultural pests.

Galerucella calmariensis and *G. pusilla* are joining three native species of Galerucella in North America. *Galerucella nymphaeae* has a broad range of aquatic hosts in the U.S. and Europe including water lily and purple loosestrife. *Galerucella stefanssoni* uses cloudberry (*Rubus chamaeomorus*) as a host plant, and *G. quebecencis* has as its host marsh-flower (*Potentilla palustris*). Since the two European beetles are nearly identical both morphologically and in their life cycles, they will mostly be treated as a single entity.

Description

Galerucella calmariensis and *G. pusilla* range from 4 to 6 mm in length and are about half as wide as they are long. Coloration is light brown, sometimes with a dark stripe located at the margin of each elytra (hard outer wings). It is not possible to differentiate between the two species in the field due to variability in key characteristics. It is sometimes possible to differentiate between the two with some accuracy using spots on the pronotum (one mark for *G. calmariensis* and two tiny dots on *G. pusilla*) although variability is present here as well. Some insects of either species may exhibit no markings, and adults emerging from pupation do not harden and develop any markings for up to 10 days from emergence.

Life Cycle in the Midwest

In spring (late April or early May) over-wintering adults emerge from soil and litter below or near old loosestrife plants. They feed for several days on new foliage and then begin to reproduce. Females lay eggs in masses averaging five to seven eggs per grouping, which may be placed low on the stem, at leaf axils, or on leaves. The egg-laying period occurs from mid-May to mid-July with the peak in May and June. An individual female may lay up to 500 eggs during this period. Larvae emerge from eggs in seven to ten days and feed in and on shoot tips. When larvae begin feeding, the adults migrate to other nearby plants, possibly to reduce competition for food. Differential feeding (younger larvae feed only on shoot tips and flower buds while later instars are less discriminating) reduces competition. Defoliation of plants by larvae can be complete, resulting in their migration to nearby plants. Larvae feed and molt for about three weeks before moving down into the soil or litter to pupate. Where water levels are higher, larvae may pupate inside the stem by burrowing into aerenchyma tissue (plant tissue containing cells composed primarily of air giving aquatic plants buoyancy, for example). Upon emergence, the new adults harden in about seven to ten days, and then feed until moving into the litter or soil below to over winter. This period of emergence occurs typically from July to September. When warm periods are extended there may be a short period of some mating and oviposition prior to entering into hibernation. The total maturation time from egg to adult is approximately 30 to 40 days.

Ecology

Both *Galerucella* species are found inhabiting loosestrife throughout the plant's natural range in Europe and Asia. In nature, both species are host-specific in regards to oviposition (i.e., will lay eggs only on purple loosestrife) and are primarily specific feeders as well. In research trials where purple loosestrife has been completely defoliated, newly emerging adults have been noted feeding to some extent on winged loosestrife (*Lythrum alatum*) and swamp loosestrife (*Decodon verticillatus*) and other plants. This type of feeding is reported to be rare under field conditions. Both *Galerucella* species occupy the same level in the food chain, but a number of specializations allow them to avoid competition. These include species-specific attractants (pheromones) used for aggregation and mating, male courtship behavior, adult dispersal, and differential feeding of larvae.

Impact on Host

Galerucella beetle adults inflict a "shot hole-feeding" pattern eating small (1-2 mm) holes through foliage. Larvae produce a skeletonized feeding pattern on the leaf, eating the softer tissues and leaving the more lignified (tougher, less digestible) veins. Larval damage to flower and shoot buds reduces plant growth and inhibits flowering. Adult and larval leaf damage greatly reduces the photosynthetic capability of purple loosestrife. This may reduce starch stores in the roots and can result in over wintering mortality in the plant. Photosynthetic inhibition results in reduced stem height and root length, both essential to overall plant vigor. The resultant weakening and/or death of the loosestrife plants provide an opportunity for native plant species such as the cattails (*Typha latifolia* and *T. augustifolia*), grasses, and sedges to return.

The beetles have the ability to fly between plants or plant clusters, and larvae, pupae, and adults can float, allowing current or wind to move them to nearby plants. The impact on permanently flooded sites is not as successful. Long-term standing water may be detrimental to *Galerucella* development since pupation is difficult under these conditions. The *Hylobius transversovittatus* weevil is not as effective on flooded sites because *Hylobius* larvae are not able to survive in roots under permanently flooded conditions.

It is expected that the establishment of permanent stable populations of *Galerucella* on purple loosestrife will reduce this plant to levels that may be tolerated by North American wetland ecosystems.

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Appendix G
Life History and Ecology of *Hylobius transversovittatus*

Hylobius transversovittatus is a member of the weevil family of beetles (*curculionidae*). This family includes approximately 40,000 known species of weevils worldwide with 2,500 known species in North America. Weevil adults feed on foliage and flowering parts while the larvae mine roots and stems. Some weevils are serious agricultural pests. The weevils of the genus *Hylobius* are primarily found on conifers in Europe and North America where some are considered significant forest pests.

Description
Hylobius transversovittatus adults average 10 mm in length, but can range from 5 to 15 mm in length. Coloration is dark brown with white tufts of hair arranged in two rows running laterally across the elytra (hard outer wings). The thorax and head of the adults taper to a downward-curved snout.

Life Cycle
The nocturnal adults emerge from over-wintering in mid-April of May and feed on purple loosestrife foliage for about three weeks before females can lay eggs. Females place 1 to 3 eggs each night, generally in soil close to roots and in purple loosestrife stems close to its base. When stems harden, eggs are laid exclusively in the soil. Up to 200 eggs may be produced by a mature female during the summer season with the peak period being June and July. Upon hatching from eggs, larvae laid in stems feed in the pith and burrow downward to the roots. Larvae hatching in soil feed on the tender rootlets, then burrow into the root cortex. Larvae continue to feed on the roots during their development and mining of the roots is indicated by light brown fecal material left in the wake of their feeding. Complete maturation takes one to two years when larvae pupate at the top of the root, then emerge as adults and feed on leaf edges. Larvae in all stages (instars) are capable of over-wintering in the root tissue.

Ecology
Hylobius transversovittatus is found throughout purple loosestrife's native range in Europe and Asia, inhabiting the plant everywhere it is found except in sites that are shaded or permanently flooded. Adults and larvae can survive submergence for a few days, but permanent flooding results in mortality. Adults disperse twice in a year, in the spring, after emergence from over wintering, and at the end of the summer when offspring emerge from pupation. The primary means of dispersal is by walking, which makes for slow spread of the insect.

Impact on Plant
Adults feed on leaves of the plant, beginning at the edges and working inward, towards the mid-vein. The major impact on the purple loosestrife plant, however, occurs from the activity of larvae mining the roots. Larvae laid in stems mine pith as they travel to the roots, damaging vascular tissue and disrupting transport of photosynthetic products (photosynthates) to the roots for storage. Mining of the roots reduces the available supply of photosynthates to the plant, which can eventually lead to plant mortality. Mining also weakens root structure making them brittle and more susceptible to mechanical damage if disturbed. The number of larvae present per root and root age governs plant impact. One or two larvae in the roots of a plant only a few years old can significantly impact that plant, while the same number of larvae in an older root may produce little impact. It is expected that these insects alone or working in concert with *Galerucella* calmarinensis and *G. pusilla,* two leaf feeders, also released on purple loosestrife, will reduce this plant to more stable levels in North American wetlands.

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Appendix H

Site Selection Guidelines for Release of *Galerucella* Beetles

A number of factors are important in creating the greatest potential for successful establishment of *Galerucella* spp. against purple loosestrife. The most critical factor is to avoid of sites with known adverse characteristics. Sites that have the most favorable combination of criteria should be favored as release sites.

Unacceptable Conditions

1.) Sites should not be subject to direct disturbances that remove purple loosestrife or kill beetles. Sites that may be developed, mowed, dredged or receive herbicide applications against purple loosestrife are not suitable.

2.) Sites that will be sprayed with insecticides against adult mosquitoes are not suitable.

3.) Sites with permanent flooding are not suitable. The beetles can tolerate occasional flooding, particularly in spring, but over wintering success will be enhanced on sites without permanent standing water.

4.) As a precaution, sites containing mixtures of purple loosestrife and the native winged loosestrife, Lythrum alatum, or swamp loosestrife, Decodon verticillatus, should be avoided. While these beetles are considered to be host specific and unlikely to cause serious damage to non-targets, avoiding opportunities for incidental feeding on related plants is desirable. Alternative means of purple loosestrife control should be considered where populations of these plants occur.

Favorable Attributes

1.) Sites should be accessible for release and continued monitoring of beetles. Physical access (a nearby road or lane) is required to transport beetles to the site. Legal access (landowner permission) is required for initial release and subsequent monitoring.

2.) Sites should contain at least 500 purple loosestrife plants in a 100-yard radius.

3.) Sites that are open to sunshine and not shaded are more easily established.

4.) Releases in mixed plant communities are encouraged as it is expected that competition from other plants will accelerate control. Sites containing other invasive species such as phragmites or reed canary grass should receive low priority.

5.) Establishment may be more reliable on sites that contain a mixture of young and old purple loosestrife plants.

Appendix I
Wetlands: Habitats in Peril

In the past, people generally perceived wetlands as unattractive, unproductive, wasteland areas that might better be drained and "put to some use." Although people often lament the fate of tropical rainforests, we sometimes fail to see the importance of preserving and restoring our own wetlands, and we continue to ruin them at an astonishing rate. During a single hour, 60 acres (an area equivalent to 58 football fields) of wetland habitat are destroyed in the U.S.!

What Is a Wetland?

Wetlands cover about 6% of the earth's land surface, and can be defined rather simply as areas that are part land and part water and in which water is the controlling environmental factor. The federal government has recently developed several more complex definitions, but they are lengthy and controversial. In general, wetlands exhibit the following characteristics:

1.) The water table (the upper limit of that portion of the ground that is entirely saturated with water) remains at or near the surface, and water covers the land at least part of the year.

2.) The soils are hydric (wet for most of the year and low in oxygen).

3.) The plants that grow there are adapted to life in water or saturated soil (hydrophytes). Plant material accumulates rapidly in wetlands and decays very slowly.

Wetlands occupy areas between terrestrial (land) and aquatic (water) habitats and have developed ecosystems that are uniquely their own.

Water in the System

Wetlands can be classified into a variety of forms, each with its own special profile. Swamps, marshes, bogs, seeps, and fens are perhaps the most familiar. The U.S. has many different wetland habitats that vary in climate, water supply, soil type, and plant and animal residents. Wetlands may be:

- Saturated for at least part of the year
- In permanently standing water
- Associated with the seasonal changes that occur along a river
- Formed directly or indirectly by the action of ancient glaciers
- Characterized by organic soils (soils made primarily from decayed plants)
- Predominately composed of inorganic (mineral) soils
- Composed primarily of grasses
- Forested

No two wetlands are alike, and each is an important ecosystem with influence far beyond its perimeters.

Wetlands were formed either by the action of glaciers or by rivers. During the last Ice Age, great chunks of ice broke off from the main bodies of the glaciers and were left behind to melt and form lakes. In other areas, glaciers merely scooped out shallow depressions that allowed water to accumulate as the ice retreated.

Wetlands formed by rivers are of many types, including oxbow marshes, floodplain bottomlands, and backwater lakes. When a meandering river changes course and leaves a portion of its channel isolated except when the river floods, an oxbow pond is formed. In time, the pond may fill with soil and become an oxbow marsh. Floodplain bottomlands are created by periodic flooding and include bottomland forest, swamp, and marsh habitats. Backwater (bottomland) lakes form when soil and sand settle out of river currents and form long islands in the river. If such an island

becomes high enough to completely separate the side channel from the main river, a bottomland lake is formed. Human activities can also create or destroy wetlands. Impoundments, excavations, and the construction of dikes produce some wetlands.

The types of plants and animals found in oxbow marshes and backwater lakes are determined largely because of the periodic flooding of these areas by the main river. Annual flooding is a predictable and recurring phenomenon, so many organisms have evolved adaptations that enable them to exploit the seasonally expanded habitat and the food brought in by the flood. Times of low water, however, are just as important as flooding. A low water level concentrates fish into shallow pools where herons and egrets obtain food for nestlings, it exposes mudflats where moist-soil plants grow and produce seeds sought by waterfowl; and it allows soils to drain and be exposed to oxygen, thereby speeding the processes of decay and the recycling of nutrients.

Beavers also play a role in the formation of wetlands. When a beaver dams a stream, water accumulates behind the dam and a pond, or small lake, forms. When the beaver abandons the site, usually because local food sources have been depleted, the dam eventually begins to leak, and a wetland of sorts forms upstream. Wetland plants and animals persist in the area as long as the soil remains saturated.

Wetlands can have either mineral (in-organic) or organic soils. Mineral soils are composed largely of sand, silt, or clay. Organic soils, generally called peat or muck, are formed from plant material that has partially decayed in wet ground that is low in oxygen (anaerobic). These soils are low in oxygen because standing water has partially insulated the plant material from the atmosphere. Organic soils take up (absorb) chemicals from the environment better than inorganic soils, an important attribute that will be discussed later in more detail.

Hydrology, the study of water on or below the earth's surface, is important in classifying wetlands. In general, wetlands have two sources of water: surface water from precipitation (rain, snow, ice) and groundwater (the water found below the surface of the soil). A depression that is deep enough to extend below the water table forms a wetland fed by both groundwater and surface water. A depression that does not extend below the water table receives only surface water, such as precipitation and runoff from the surrounding land. Wetlands found on slopes, usually surrounding a lake, pond, or stream may receive water from several sources, including runoff and floodwater. The length of time the area remains saturated depends on the degree of slope, soil characteristics, and the frequency of flooding or runoff from precipitation. Knowing how a wetland receives its water (its hydrology) is crucial for protecting and managing the wetland, although it is not always easy to determine the source of water.

Flora and Fauna

Plants are important in helping us decide what is, or is not, a wetland. Wetland plants are visible and easily identified. Water depth is, perhaps, the most influential physical factor in determining the kinds of plants that inhabit a wetland. There is a greater diversity of plant species in shallower water, because more plant species are adapted to moist-soil conditions than to open water (strictly aquatic conditions).

Many interesting plant types occur in wetlands, including many species of vascular plants. Vascular plants are those with both xylem (supporting and water-conducting tissue) and phloem (food-conducting tissue). Floating-leaf plants, such as water lilies, are rooted deep below the surface of the water and send up broad, flat leaves that rest on the surface where photosynthesis occurs. Nutrients move between the leaves and the underwater roots via the plants' long, slender, flexible stems. Free-floating plants such as duckweeds are not rooted but remain on the surface of the water, usually with their roots dangling. By contrast, emergent plants, including cattails, arrowheads, and bulrushes, are amphibious; that is, they grow with their roots in wet soil for all or part of the year and send up leaves that stand erect above the surface of the water. Submerged plants like pondweeds are also rooted in the soil, but their stems and leaves remain entirely underwater. Other plant types that occupy the drier portions of wetlands include moist-soil plants (sedges), moist-soil shrubs (e.g. buttonbush and red osier dogwood),

and moist-forest species (tamarack, bald cypress, and silver maple). Some wetlands contain all of these vegetation types, but others have only one or two. Along with water chemistry and hydrology, differences in vegetation help determine the presence of a wetland and to distinguish among the various types of wetlands.

Identifying a wetland by looking at its animals is more difficult than relying on its plants. The degree to which animals depend on wetland habitats is sometimes determined by their mobility and can vary greatly depending on the season. Although many mammals visit wetlands, only a few species (most notably the muskrat, beaver, and river otter) are adapted to water and to living among water-loving plants. Several other species, from the rare rice rat and swamp rabbit to the common white-tailed deer, raccoon, and mink, use wetlands to various degrees. The swamp rabbit, for example, is rarely found far from water and inhabits floodplain forests, cypress swamps, and areas where low ridges alternate with wooded sloughs or grassy marshes. Rice rats live in areas characterized by standing water with a dense cover of emergent vegetation, including sedges, rushes, and cattails.

Birds are unique among wetland inhabitants because many are migratory and rely on widely separated wetlands on a seasonal basis. Some migrant species of birds may return year after year to the same wetlands to feed and raise their young. Other migrant species do not nest in wetlands but depend on them to forage and rest during long migrations. Waterfowl, shorebirds, and numerous songbirds rely on wetland habitats. Because the habitat requirements of some species are highly specific, and others require several different habitats, the conservation of a great diversity of wetland habitats or wetland complexes is essential to the preservation of the full range of bird species.

Most amphibians require water to reproduce, and many reptiles and amphibians also find wetlands ideal foraging or feeding grounds. In spring and early summer, wetlands are alive with calling toads and frogs, their mating success soon evidenced by strings of eyelike eggs floating in the still waters. Frogs and toads will eat just about anything that moves and is of an appropriate size. In turn, they are food for many species of snakes, birds, and mammals. Many kinds of snakes live in or near water. They are excellent swimmers and hunt fish, frogs, and other organisms associated with wetlands. Although the role of all of these creatures in the overall "balance of nature" is poorly understood, their existence is undoubtedly essential to many other organisms.

Wetlands also serve as breeding grounds for many species of fish. The variety of fish species found in a marsh, however, is relatively small and includes only those that can tolerate muddy conditions and relatively warm water for at least part of the year. The pumpkinseed sunfish is a species typically found in ponds and marshes.

Although most of us are unacquainted with the invertebrates, the least conspicuous but most abundant animals in any wetland habitat, they play an essential role in making plant energy available to other animals. Among the invertebrates present in midwestern wetlands are protozoa, sponges, flatworms, worms, crustacea, mollusks (clams and snails), and insects. Although most insects are terrestrial, a significant number (about 10%) are adapted for living in water. The most common insects of wetlands are crawling water beetles, giant water bugs, water scorpions, dragonflies, and mayflies. In some types of wetlands, such as deep and shallow-water marshes, mollusks are dominant and form an important food source for fish and diving ducks. The presence of unionid mollusks (larger type clams) is also a fairly reliable indicator of relatively clean, pollution-free water.

The plant and animal communities found in wetlands are extremely complex. Wetland plants and animals are tied to one another through food webs and nutrient cycles.

Wetland Types

There are dozens of midwestern wetland types. Even a cursory understanding of a few types and their remarkable diversity makes it clear why we cannot settle for preserving or restoring only "major" wetlands or a generic, all-purpose wetland.

Floodplain forests usually occur along stream and rivers. Because these forests are flooded frequently, they have a lower diversity of tree species than forests located on higher ground. The under story is open but often choked with nettles and vines. Rotting logs and woody debris deposited by floodwaters are abundant. Typical trees of midwestern floodplain forests are silver maple, cottonwood, red maple, and sycamore. The soils that support these forests are usually mineral.

Marshes are dominated by emergent plants that grow with their stems partly in, and partly out of, the water. These include sedges, bulrushes, pickerelweed, and cat tails. Water depth in marshes ranges from zero (saturated soil) to, perhaps, six feet. Both floating-leaf plants and submerged aquatic plants (water lilies and pondweeds, respectively) are frequently associated with cattails, an emergent species. The soils that underlie marshes are sometimes mineral but usually organic. Marshes are highly productive habitats where hundreds of species of birds, insects, and other wildlife spend most of their lives.

The productivity in any ecosystem is usually measured in terms of the living things that it produces (biomass). Two factors account for the high productivity of marshes. One is the ability of marsh plants to capture large amounts of energy from the sun and transform and store much of it as chemical energy in the form of plant tissue. The other is the efficient recycling of nutrients already produced, recycling accomplished as dead plants and animals decompose and become nutrients used by living organisms.

Swamps are dominated by woody plants and can be divided into two categories: forested and shrub swamps. Forested swamps are often dominated by bald cypress and water tupelo. The cypresses may reach prodigious size. (In Illinois, the largest is more than 34 feet in circumference. Cypresses are also among the oldest living organisms on earth. In southern Illinois, thousand-year-old specimens can still be found.) The soil in forested swamps may be either organic or mineral but usually has a topmost organic layer underlain with a mineral soil. Shrub swamps are similar to forested swamps except that less of the vegetation is in the form of trees. Typical plants include speckled alder, buttonbush, and dogwood growing in mostly mineral soils.

Bogs are found mostly in the northern Midwest, usually in glacial depressions with restricted drainage. Bogs may be forested or grassy or have tall or short shrubs. Because of poor drainage, bogs are highly acidic (low pH), and the plants that inhabit them must be adapted to this condition. Bog plants include sphagnum moss, various orchids, poison sumac, tamarack, and interesting carnivorous types such as the pitcher plant and sundew. Bog soils are always organic because of the incomplete decay of plant material in the acidic, low-oxygen water. The buildup of plant material forms a substance called peat, which forms a floating mat over the water. Highly acidic conditions do not allow decomposers such as bacteria to flourish, and this acidity, combined with the low nutrient content of the soil, inhibits the invasion of potentially competing plant species.

Seeps and springs may be acidic (low pH) or basic (high pH), depending on the materials through which the groundwater flowed before reaching the surface. Seeps are common along the edges of moraines, ravines, and terraces where the groundwater meets a layer of material impervious to the downward movement of water. As a result, the water flows outward over a wide area until it reaches the surface, often at the base of a bluff or ravine. Springs have a more concentrated flow of water from a more clearly defined point in the soil. The alkalinity or acidity of the water determines the type of plants found in these habitats; the vegetation includes ferns and orchids and unusual plants such as skunk cabbage.

Fens are a type of wet meadow fed by alkaline water (high pH or basic), usually from a spring or seep. Like bogs, fens occur on organic soils and can be shrubby, grassy, or even forested. All known fens in the U.S. are associated with the glaciated region of the East and Midwest. Fen vegetation forms a unique community of calcium-loving plants such as shrubby cinquefoil, Ohio goldenrod, and grass-of-Parnassus. Fens are extremely sensitive to disturbance because any change in groundwater, either by pollution or changes in water level, drastically alters the habitat.

Wet prairies have a soil that is almost always organic and generally saturated. Some standing surface water is usually present during winter and spring. As a result, the plant diversity of wet prairies is less than that of drier prairie sites. Among the typical wet prairie plants are sedges, cord grass, and blue flag iris. Most Midwestern wet prairies have been drained and are now farmed.

Swales or sloughs occur around the sandy shores of the Great Lakes in depressions between old dunes. The plant community is similar to that of a grassy fen and contains plants that tolerate calcareous (basic) conditions–for example, shrubby cinquefoil, bladderwort, and arrowgrass. Swales or sloughs also occur in forested areas, often on the floodplains of fairly large streams.

Ponds and lake margins are classified as wetlands because they support typical moist soil and water-loving plants. In addition, they are often surrounded by marshes or wet forests. Soils may be organic or mineral. Typical plants include arrowhead, pickerelweed, and water lily. If left undisturbed, lakes eventually fill in and are transformed into wetlands as sediment is deposited by feeder streams and carried in runoff from adjacent land.

Chains, Webs, and Pyramids

A basic process in wetland ecology, as in all ecology, is energy flow–the movement of chemical energy within a food chain. Microscopic green algae produce chemical energy in the form of plant tissue from carbon dioxide, sunlight, water, and other nutrients (photosynthesis). Algae are often called the green grass of the water world, and they can give water a pale green color when they occur in large numbers. Algae are so small that a thousand medium-sized algae side by side might scarcely measure an inch. The second link in the food chain might be a mayfly nymph that feeds on the green algae. A pickerel then eats the mayfly. The pickerel might ultimately become a meal for a great blue heron. Several of these simple food chains interacting together with organisms that feed on dead material (detritivores or decomposers) and those that eat both plants and animals (omnivores) form a more complex structure that we call a food web.

When scientists study the structure and functioning of food webs, they use a specialized vocabulary to describe the relationships among various organisms. A term often used in the study of food webs and energy flow is trophic, a word that comes from a Greek root meaning to nourish. Trophic structure, then, is the nutritional interrelationships among organisms in a particular food chain or web, and in this context the word nutritional is virtually synonymous with the word energy.

Another way of understanding trophic structure, besides the food chain and food web, is to envision a pyramid composed of several layers. Each layer depends on those supporting it and represents a trophic level. Plants compose the base or bottom trophic level of the pyramid. Because they absorb the energy of sunlight and convert it into growth, plants are called primary producers. Organisms in the layer just above the primary producers are called primary consumers. Because primary consumers feed on plants, they are called herbivores. Primary consumers, however, do not merely consume food from the layer below them but are also food (or producers) for organisms in the layer above them, the carnivores. Carnivores feed on other animals and are called secondary consumers because they feed on the primary consumers, the herbivores. A particular food pyramid may have several layers of carnivores, which may feed upon other carnivores in a fairly long succession. All trophic pyramids, however, ultimately come to a point with a few "top" carnivores.

Energy

Energy flow is a one-way street. Energy is lost as it moves from one trophic level to the next, or from one organism to the next. Consequently, any ecosystem can support only a limited number of organisms, determined by the available energy. This number is called the carrying capacity of the ecosystem.

Wetland Benefits

Wetlands, like any habitat, have an inherent beauty and interest that provide a convincing rationale for their preservation. HOowever, they also serve us in ways that are essential in more immediate and selfish terms. Wetlands play a unique and irreplaceable role in maintaining the quality of our water, in controlling floods, and in providing habitat for an incredible diversity of species.

Wetlands have a profound ability to improve water quality. They reduce turbidity (cloudiness) by slowing the flow of water and allowing particles to settle out. Aquatic plants also play a role in reducing turbidity because they catch and remove solids from the water. Wetlands also work in several ways to filter out various types of pollutants, from the nitrogen and phosphorous in agricultural fertilizers introduced by runoff to the variety of chemicals in municipal and industrial wastewater. Algae and other wetland plants take up these chemicals from the water itself or from soil particles, and convert them to plant tissue. When the plants die some of these materials remain in the partially decayed plants and are deposited as peat or muck. Bacteria and fungi convert the remainder of the nitrates from decaying plants to gaseous nitrogen that is released into the air. In one study nearly 90% of the polluting nitrates deposited from surrounding farmland were removed by an Iowa marsh by the time the water had reached its outlet. Cattails and bulrushes were primarily responsible for this filtration.

Excess nutrients and polluting chemicals are also filtered out by becoming locked to particles of sediment in a process called ion exchange. Sediments (including sand and soil particles of various sizes) settle quickly to the bottom of the wetland floor, taking the pollutants out of circulation. In addition, silt (small soil particles of uniform size) eventually settles to the bottom when suspended in water flowing slowly through tangled, dense growths of wetland plants.

Wetlands with main channels or rivers cutting through them operate as filters in ways that differ from the filtering action of wetlands such as marshes and bogs with no channels. Many wetlands encompass rivers that wander slowly through broad floodplains with numerous ponds, oxbows, and sloughs. During flooding, water covers much of the floodplain, and the river becomes a slow-moving lake in which some pollutants are trapped by soil particles and settle out. Other pollutants may be absorbed directly by wetland plants or filtered out as water seeps down through the wetland soil to become groundwater. Floodplain wetlands, therefore, act as a buffer between the main channel of the river and the surrounding agricultural and urban landscapes. The removal of these buffering wetlands by drainage, channelization, or straightening of the main channels of the river, disrupts this remarkable filtering system and allows pollutants to enter the river. For example, a recent government report described widespread herbicide contamination of the Mississippi River, its tributaries and associated wetlands each spring because of runoff from agricultural land. In 27% of samples collected in the study, levels of atropine (a common herbicide used in growing corn and known to cause liver and kidney problems) exceeded the maximum levels allowed by the Environmental Protection Agency in drinking water.

Wetlands without channels, such as sedge meadows, marshes, and bogs, filter pollutants without the benefit of flooding from a nearby river. These habitats generally contain organic soils and are therefore good pollution traps. Peats and mucks have excellent filtering capabilities and attract polluting chemicals. Wetlands that are very shallow (less than a foot deep) and that have a widely spread flow pattern allow pollutants to come into maximum contact with the soil surface and are, therefore, highly efficient filters. But even these forgiving wetlands have their limits. The addition of any pollutant has a deleterious effect on habitat, even when that effect, for example accelerated plant growth, seems innocuous at first. Plant species, such as cattails, that are adapted to use these excess nutrients begin to thrive and soon become dominant. As a result, species diversity is reduced, and the quality of the wetland as wildlife habitat is seriously impaired.

Wetlands also play a significant role in maintaining appropriate water levels during floods and droughts. Wetlands reduce flood peaks because they store rainfall and then slowly release it. During drought years, marshes and other wetlands feed stored water back into rivers and thereby help to maintain adequate water levels.

Flood damage for any given year, however, can be staggering. Although millions of dollars are spent on dams and levees, flood damage continues to increase. The main cause of the increase in flooding is the destruction of floodplain wetlands; nature's sponges that store excess water and then slowly release it. In Illinois, for example, the Illinois River once encompassed nearly 400,000 acres of wetlands that could potentially flood yearly. By 1926, nearly

half of those acres had been drained, leveled, and converted to farmland. Much of the water that originally spread over these broad floodplains now flows down the main river channel and contributes to flooding downstream. Flood control can be achieved only by giving back to the river some of the floodplain we have taken from it.

Straightening a river or stream has a detrimental effect on the filtering capabilities of its wetlands and on flood control. Water runs faster in straightened streams, allowing less time for sediment and pollutants to settle out or be removed by vegetation. Straightened, denuded streams also allow for virtually no absorption and storage of excess water, thus promoting flooding downstream. For wetlands to serve their biological functions of filtration and flood control, they must be preserved intact, not leveled, drained, straightened, or stripped of their natural vegetation.

Another function of wetlands is to provide habitat for wildlife and to support an incredible diversity of species. Acre for acre, they are the most productive temperate (non-tropical) ecosystems. More plant material is produced in a marsh in the form of cattails and bulrushes than in a cornfield. This tangled mass of luxuriant growth is used all year long by wildlife for food, cover, and nesting habitat. Wetlands provide rookeries for wading birds such as the great and little blue herons and nesting or feeding sites for songbirds, raptors, and various mammals. Wetlands are important nurseries for aquatic life and support both common and rare species, from the familiar green sunfish to the unusual banded pygmy sunfish. As the marshes, bogs, and fens have disappeared, however, so has the wildlife. Some species have simply declined in numbers, but others, such as the whooping crane and trumpeter swan, have decreased the extent of their nesting areas and have nearly ceased to exist as species altogether. Today wetlands are home to about one-third of all plant and animal species that have been recognized as threatened or endangered.

The price we, and future generations, pay for the loss of a species can never be known. Even a tiny spider may prove to have incalculable economic value. For example, scientists in Utah and Illinois have recently announced that an environmentally safe pesticide has been developed using a genetically engineered spider-toxin gene. In nature, an insect would receive the toxin via the spider's venom. In the laboratory, scientists have added the cloned toxin gene of the spider to a naturally occurring virus known to be modestly effective in the control of leaf-eating insects. The virus can then produce the toxin internally. When an insect eats the virus, the insect becomes paralyzed and dies. If further developments prove successful, an environmentally safe pesticide will be available for major row crops such as corn and cotton. A variety of natural toxins hold promise in the search for safe pesticides, but scientists will require the full repertoire of plants and animals. A lost species could be a lost opportunity.

From an aesthetic point of view, the appeal of wetlands cannot be measured in dollars and cents; yet to many people this aesthetic value is the most important of all. Wetlands are beautiful. There is a mystery about them (e.g. a great blue heron trying to eat a water snake it has caught but that is entwined around its beak, a raccoon patiently trying to solve the riddle posed by a tightly closed mussel) that generates excitement, even awe, in the observer. Wetlands are part of our natural heritage, sites for seclusion and reflection as well as for more active types of recreation like canoeing and photography. These wetlands, though characterized by an English journalist in the 1860s as "cheerless, miserable places, sacred to the ague and fever," are now recognized to have irreplaceable economic, ecological, aesthetic, and philosophical value.

Wetland Status Report

Estimates suggest that during the 1600s more than 200 million acres of wetlands were found in what was to become the lower 48 states. Since then, over half of those wetlands have been drained and converted to farms. Estimates made in the 1980s indicate that only 103 million acres of wetlands remain. In many places, wetlands continue to exist only because these remnants are considered too difficult or expensive to drain or because the land to be recovered is deemed not worth the effort. In relatively few cases wetlands are intentionally preserved because their value has been recognized.

Illinois provides a stunning example of how humans have changed the landscape. After the last glacier receded, there were approximately 8.3 million acres of wetlands in what is now Illinois. Today, only about 1 million acres remain, and only 6,000 acres are undisturbed. Most were drained between 1879 and 1930 to reap the enormous economic benefits they offered. In the pursuit of tillable land, settlers often drained areas that would better have been left in their natural state. Indeed, in later years some of the floodplains that had been drained for row crops reverted to their un-drained state when frequent flooding made agriculture unprofitable.

By the 1920s, most of the artificial drainage of Illinois wetlands was complete, and by 1937 nearly 750,000 acres of river bottomland had been incorporated into drainage districts. These districts, made legal by the Drainage Levee Act and the Farm Drainage Act of 1879, allowed landowners to pool their financial resources to drain land. Of the 35 million acres of Illinois, more than 17% is now part of organized drainage districts, and more than 27% of the state's agricultural land is drained in one fashion or another. When urban and industrial development is added to the story, we find that more than 90% of the original wetlands of Illinois have been destroyed. Most other Midwestern states have experienced similar declines.

Although the recent history of our wetlands is bleak, we should not assume that the final chapter has been written. Restoration is feasible, especially when sites are chosen carefully. Preservation is also possible; and if the remaining undisturbed sites are small, a slow but steady linkage of some of them is plausible. In fact, small wetlands may have greater ecological integrity than larger, disturbed ones. Ecological integrity simply means that a substantial percentage of the wetland species remains relative to the number that occurred there when the area was pristine. Thus, these small areas of diversity can serve as epicenters for the reinvasion of plants and animals into much larger areas undergoing restoration. In the meantime, they act as habitat corridors through which wildlife move in their search for adequate food and cover.

Preservation and Restoration

More than 117 million acres of wetlands have been lost in the lower 48 states since colonial times, more than half of the original wetlands. Ten states have lost more than 70% of their wetlands, and the loss continues at the astonishing rate of 60 acres an hour. What can be done to halt or even reverse this trend? Although federal, state, and local laws protect some wetland habitats, these laws do not provide adequate protection. They are riddled with loopholes, and inadequate staffing and a lack of funds hamper their enforcement.

Perhaps the best and most comprehensive protection comes from Section 404 of the Federal Water Pollution Control Act Amendments, legislation that authorizes the U.S. Army Corps of Engineers to require permits for the disposal of dredged or fill material onto an adjacent wetland or into any stream with an average flow of at least 5 cubic feet per second. Typical activities that require permits are the installation of pipes and the construction of levees, rip-rap, piers, boat ramps, canals, dams, dikes, roads, and artificial islands. A request for a permit can be denied if an alternative less harmful to the environment can be found or if the activity will cause "significant degradation" of an aquatic ecosystem. Significant degradation includes violations of toxic waste discharge standards, decisions that jeopardize threatened and endangered species or harms the ecology of an individual species, and actions that threaten the diversity and stability of an aquatic ecosystem.

Although the 404-permit system is better than no regulation at all, it does not provide adequate protection because wetlands can be drained or dredged as long as the material is not deposited in a wetland. Paradoxically, the law regulates the disposal of dredge but not its removal. In addition, small projects are often approved because individually they appear to cause little harm. Cumulatively, however, they chip away at the wetland resource and ultimately may have the same impact as a few large, more obviously destructive projects.

The Soil Conservation Service is also involved with wetlands. The "Swampbuster" Provisions, enacted in 1985, made any farmer that grew a crop on any wetland converted after 1985 ineligible for federal farm program money the year the crops were grown. Because farmers could still convert wetlands and then grow crops on them only in years when crop prices were high and the farmers did not need federal aid, a 1990 law added a new provision. It made farmers who convert wetlands into cropland after 1990 ineligible for federal farm programs.

Other laws that help to protect wetlands include the Federal Endangered Species Act of 1973, a law that protects species but in actuality does little or nothing to protect habitats, and Section 10 of the River and Harbor Act, a regulation that requires permits for projects on, in, or above any navigable waters of the U.S.. To a lesser extent, floodplain zoning offers some protection to wetlands in the 100-year floodplain (the maximum area that a given stream can potentially flood once in a hundred years) by preventing filling and construction that interfere with the discharge of floodwater. In addition, wetlands can be protected by public acquisition.

So what is the job before us? Where the preservation of wetlands, and of all natural habitats, is involved, we must be uncompromising. We can afford to lose no more. Back in 1949, Aldo Leopold wrote in his foreword to Sand County Almanac, "Like winds and sunsets, wild things were taken for granted until progress began to do away with them. Now we face the question of whether a still higher 'standard of living' is worth its cost in things natural, wild, and free." Half a century of "progress" later an "enlightened" technological age is not much further along in solving environmental problems, including the destruction of wetlands. We continue to hear reports of yet another "fragile" ecosystem destroyed in the name of development, and the term environmental tradeoff has entered all too frequently and dangerously into political rhetoric. Biologists know that unaltered ecosystems are not inherently fragile but are extremely stable and sturdy. The problem is that human disruptions of these ecosystems are often massive and result in serious, frequently irreversible harm.

Both streamside and un-channeled wetlands can be restored. All that is needed is a source of water and a place for it to accumulate. Much of the agricultural land in the Midwest, for example, would revert to its former wetland state if field tiles and levees were removed. Wetland restoration is obviously not that simple, but the requisites are surprisingly attainable: a site with an adequate source of groundwater or surface water, a slope that will broaden the zone for emergent plants, and a source of native wetland plants for establishment.

Action

One of the most important ways in which individuals can help to preserve wetlands is by becoming involved in formal and informal education efforts. To know our environment, we must observe it and achieve a certain intellectual, emotional, and physical intimacy with it. Conservation organizations abound, each with its own agenda but all ultimately working to preserve natural diversity. Many of these groups are interested in wetland preservation and provide workshops, slideshows, field trips, newsletters, and legislative alerts. The Nature Conservancy, Sierra Club, Audubon Society, Izaak Walton League, and Ducks Unlimited, for example, have long and illustrious histories of preserving natural habitats and are powerful voices in the conservation movement. In addition, under the framework of the North American Waterfowl Management Plan, the U.S. and Canada are seeking to protect more than 6 million acres of important wetlands in both countries. For more information about these and other environmental organizations, contact your public library.

Taxpayers and voters, especially those who have wetlands on their property, need to be informed about the benefits of wetlands and the need to preserve and restore them. But perhaps the most crucial group to reach is our youngest citizens - the future guardians of our wetlands. Through their earliest exposure to science on up through high school and college courses and through organized activities like 4-H, FFA, and Scouting, tomorrow's voters can become articulate advocates for wetlands and an informed political force. It is to the mentors of that youthful audience that this publication is directed.

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