Stop the Invasion

Unwanted Plants, Bugs, and Other Pests

4-H Invasive Species Project
Stop the Invasion: Unwanted Plants, Bugs, and Other Pests, the 4-H Invasive Species Project, is a hands-on, interactive curriculum through which youth develop an understanding of invasive species and their effect on ecological systems.

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This work was supported by a grant from the Pennsylvania Department of Agriculture through the Penn State/PDA Partnership Agricultural Resource Centers.

Special thanks and appreciation go to the following people who served on the development, review, editing, and pilot testing teams. This curriculum guide would not have been possible without them.
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What Is 4-H?

4-H is the largest youth development program in the United States. It is run by each state’s land-grant university as part of their Cooperative Extension program, a partnership with the USDA, state, and local governments.

The 4-H mission is to empower youth to reach their full potential, working and learning in partnership with caring adults.

4-H Mission Mandates


The mission of 4-H is to provide meaningful opportunities for youth and adults to work together to create sustainable community change. This is accomplished within three primary content areas, or mission mandates: citizenship, healthy living, and science. The educational foundation of 4-H lies in these three mission mandates.

Citizenship

Since its inception, 4-H has placed emphasis on the importance of young people being engaged, well-informed citizens. By connecting to their communities and community leaders, youth understand their role in civic affairs and expand their role in decision-making processes. It’s clear that civic engagement provides the foundation that helps youth understand the “big picture” of life and find purpose and meaning.

Healthy Living

Healthy food and nutrition have been addressed by the program since its inception in 1902. Having a long history of promoting healthy living among youth and their families, 4-H has become a national leader in health-related education. The 4-H healthy living mission mandate engages youth and families through access and opportunities to achieve optimal physical, social, and emotional well-being.

Science

The need for science, engineering, and technology education is essential for today’s young people. 4-H programs prepare youth for the challenges of the twenty-first century by engaging them in a process of discovery and exploration.
The Experiential Learning Model


The activities in the Stop the Invasion: Unwanted Plants, Bugs, and Other Pests curriculum were written to emphasize the use of inquiry and the experiential learning model. The experiential learning model emphasizes the importance of youth being involved in each of the five stages of the model throughout their learning experiences. Youth experience the learning activity, share their experiences with others, process what was important about the experience, generalize how their experience relates to everyday experiences, and then apply the skills they gained to other parts of their lives. “Do, Reflect, and Apply” are ways to connect life skill development to any subject matter learning experiences.
Introduction
Understanding what invasive species are and their potential impact on the health of ecosystems is important in today’s world. According to the United States Department of Agriculture (USDA), invasive pests are considered the second greatest threat to biological diversity after habitat loss (HungryPests.com). Invasive species have impacts on people in their everyday lives. Some invasive species are simple nuisances, while others can have devastating economic impacts. Individuals can play an important role in eliminating the spread of invasive species. Surveillance, management, and eradication are important tools to be employed to mitigate the effect of invasive species both biologically and economically. Stop the Invasion: Unwanted Plants, Bugs, and Other Pests will help youth develop an understanding of invasive species and the role they can play in solving this real-world issue.

Stop the Invasion: Unwanted Plants, Bugs, and Other Pests, the 4-H Invasive Species Project Curriculum Guide, was developed in response to expressed educator needs for a hands-on, interactive curriculum to help youth understand the threat of invasive species. This curriculum applies best practices in experiential and inquiry-based learning methods to help youth expand their knowledge of invasive species and discover the role they can play in surveillance, management, and eradication. Developed specifically for youth in Pennsylvania, these lessons focus on Pennsylvania ecosystems and invasive species of current concern in the Commonwealth.

How to Use This Curriculum Guide
Stop the Invasion: Unwanted Plants, Bugs, and Other Pests is a hands-on, interactive 4-H project. Appropriate for the formal classroom setting, this curriculum was designed to complement existing school science curricula providing hands-on learning. Each lesson’s educational objectives have been articulated and linked to corresponding Next Generation Science Standards (NGSS), specifically for school audiences.

Designed with a high degree of flexibility, however, this curriculum can also be delivered in nonformal and informal youth development settings, such as youth groups, afterschool programs, day camps, and residential camp settings. Stop the Invasion: Unwanted Plants, Bugs, and Other Pests is especially suited for delivery in 4-H club and 4-H camp settings.

Educators/facilitators/leaders need only possess a basic understanding of biological processes to lead this curriculum. Each lesson in the Stop the Invasion: Unwanted Plants, Bugs, and Other Pests 4-H project curriculum guide contains sufficient background information and references for knowledgeable facilitation.

The target audience for this curriculum is middle school youth; however, each lesson is adaptable to youth in lower or higher grades.

Facilitators will find that the six lessons in this curriculum have been developed to build on knowledge sequentially. The lessons can be lead independently as well, provided youth have the prerequisite knowledge to achieve the educational objectives. Each lesson is neatly organized to help the educator lead the activity confidently. The lesson format includes the following:

- Educational objectives: clearly identified expected outcomes for youth
- Educational standards addressed: for reference to NGSS
- Background information and references: to deepen the educator’s understanding of the topic
- Vocabulary: highlighted in the lesson
- Activity: hands-on, experiential, and/or inquiry-based learning experiences for youth

For each activity, facilitators will find helpful information, including:

- Time required
- Materials needed: some items are included in this curriculum guide
- Instructions
- Facilitator notes: helpful hints and/or best practices regarding activity delivery
- Processing questions: to lead discussions that help youth reflect and apply as well as process and generalize their learning experience
- References: included as appropriate for further research and information

Once youth have developed the knowledge and skills addressed in these six lessons, they are encouraged to explore the realm of citizen science. There are many opportunities for youth to contribute to the surveillance, management, and eradication of invasive species in their local communities. Your local 4-H youth development educator can assist you in identifying local citizen science opportunities. To find the 4-H program in your county, visit extension.psu.edu/counties.
Special Alert about Reporting Invasive Species

If you believe you may have observed damage or a life stage of one of the invasive species listed in the red box, another high-priority invasive species, or a new invasive species, contact a plant inspector at your regional Department of Agriculture office or an extension educator or diagnostic laboratory in your local extension office.

In Pennsylvania, contact your regional office of the Pennsylvania Department of Agriculture (www.agriculture.pa.gov) or an extension educator in your local Penn State Extension office (extension.psu.edu). You can also report invasive species to the Pennsylvania Department of Agriculture Invasive Species hotline by calling 1-866-253-7189 or emailing Badbug@pa.gov.

You can report an aquatic invasive species to the Pennsylvania Fish and Boat Commission and Pennsylvania Sea Grant using their online report form at fishandboat.com/ais-reporting.htm.

Feral swine and other wildlife invasive species can be reported to your regional Game Commission office in Pennsylvania (www.pgc.pa.gov/InformationResources/AboutUs/ContactInformation).

In Pennsylvania and several other states, you can also report invasive species using the iMapInvasives citizen science tool available at www.imapinvasives.org.

Some of Pennsylvania’s MOST UNWANTED!

- Allium leafminer
- Asian giant hornet
- Asian longhorned beetle
- Emerald ash borer
- Hydrilla
- Spotted lanternfly
- Walnut twig beetle
- Zebra mussels

Help Stop Invasive Species
CHAPTER 1
What Is an Invasive Species?

An **invasive species** is a plant, animal, insect, or pathogen that is not native to (does not originally come from) a place where it can now be found. In addition, invasive species also have the ability to spread rapidly. Invasive species are usually seen as pests and have negative effects on the environment, economy, and even human health. You may sometimes hear the words “introduced” or “alien” to refer to invasive species since they are not native to the area. However, it is important to know that not all “introduced” or “alien” species spread rapidly or are detrimental to the environment and economy. Only species that are causing problems are labeled as invasive. The arrival of an invasive species in a new place can happen in many ways. Some invasive species have been introduced on purpose, but many arrive at their new locations by accident. The following are some of the ways that invasive species are introduced:

- Scientific studies
- Landscaping
- Travel (recreational and commercial)

Each invasive species exhibits some sort of special characteristic, or **adaptation**, that helps it to survive and take over in its new environment. It is almost like invasive species have “super powers.” Here are some of the “super powers” that invasive species can have:

- Fast growth
- Can produce many young or many seeds at once (rapid reproduction)
- Can move or spread quickly (high dispersal ability)
- Ability to alter the way they grow to suit current conditions (phenotypic plasticity)
- Tolerance of a wide range of environmental conditions (ecological competence)
- Ability to live off of a wide range of food types (generalist)
- Association with humans

One example of an invasive species in the United States is the European starling (*Sturnus vulgaris*). These speckled black birds are now one of the most numerous bird species in the country. But it wasn’t always that way. European starlings didn’t even exist in the United States until the very end of the nineteenth century. The first European starlings were brought to the Central Park in New York City by some fans of William Shakespeare’s writing. The starlings were one of many birds Shakespeare mentioned in his works, and this group of fans was hoping to bring all of those birds to Central Park. There are now more than 200 million European starlings in North America. One of the things that makes European starlings so invasive is that they have a very wide range of food types. These generalists will eat bugs and berries in the wild, but they especially love to live around people where they will eat livestock feed and garbage in addition to their wild diet.

**Educational Objectives**
In this activity, participants will be introduced to invasive species using a variety of examples. To better understand invasive species, they will identify the special adaptations that make these species thrive. Participants will then design their own invasive species using their knowledge about the special adaptations that actual invasive species have.

**Educational Standards Addressed**
NGSS LS1.B: Growth and Development of Organisms
LS4.C: Adaptation

**Vocabulary**

- **Adaptation**
- **Generalist**
- **Alien**
- **Invasive species**
- **Dispersal**
- **Native species**
- **Ecological competence**
- **Phenotypic plasticity**
Activity 1

Meet the Invasive Species

**Time Required:** 45–60 minutes

**Materials Needed:** flipchart/whiteboard and markers, copies of the Pennsylvania Invasive Species Cards (available to reproduce from the Appendix on page 39), paper and pencils or other art supplies to be creative

**Facilitator Note:** During activity 1, allow youth to discover the “super powers” on their cards and share them by creating a list of super powers on a flipchart. Make sure all the youth see the pictures/specimens of each species. Add any additional super powers to your list that the youth haven’t already shared. Youth will better understand the concept if they can refer to this list as they complete activity 2.

Working with a partner, choose one of the Pennsylvania Invasive Species Cards from the deck provided. Study the picture on the front and read the back of the card to learn about the “super power” that your invasive species has. Be prepared to report back to the group the answers to the following questions about the invasive species that you chose:

1. What “super power” does your invasive species possess? (For help with this question, refer to the list of super powers in the background section or on the flipchart your helper shared.)
2. How do you think this invasive species was introduced to Pennsylvania?
3. How could this invasive species harm the environment? The economy? Human health?
4. Draw a picture showing this invasive species using its super power. How might it look if you found it in the environment?

Finally, be ready to present your invasive species to others completing the activity with you. How does the species you chose differ from other species that were presented? If someone had the same invasive species as you, how did their ideas differ from yours?
Activity 2
Create a Super Alien

Now it’s your turn to design an invasive species.

Choose two or more invasive species super powers that you learned about in the previous activity and create your own “super alien.” Keep in mind that this is not a mad scientist activity. Your super alien can only possess the biological super powers you learned about in this activity. Here are some characteristics of a super alien to consider as you work on your design:

• What type of environment will it thrive in?
• What will it eat?
• What native plants or animals will it compete with?
• How will it “take over”?
• Can it be stopped? How?

Draw a picture of your super alien and be ready to describe its super powers to your peers. You have 15 minutes to create your super alien and its “story.”

Processing Questions
1. What super powers did you choose for your super alien?
2. How might all of the super aliens designed by you and your peers affect each other’s survival?
3. Could your super alien easily move into a new environment and thrive there?
4. Which super aliens do you think would survive the longest? Which ones would thrive here in Pennsylvania?

References
Pennsylvania Department of Natural Resources, Invasive Species in Pennsylvania:
www.dcnr.state.pa.us/conservationscience/invasivespecies/index.htm
Pennsylvania Fish and Boat Commission, Aquatic Invasive Species:
www.fishandboat.com/ais.htm
Pennsylvania Invasive Species Council, Species Profiles—Insects and Other Invertebrates:
invasivespeciescouncil.com/Profiles_Insects.aspx
USDA National Agriculture Library, National Invasive Species Information Center, State Resources—Pennsylvania:
www.invasivespeciesinfo.gov/unitedstates/pa.shtml
CHAPTER 2
The Impacts of Invasive Species on Ecosystems

Now that you know what an invasive species is, let’s explore why it’s important to learn about them. You might remember that an invasive species is a living thing that can take over, or invade, a natural area like a lake, a meadow, a forest, or even your home garden. Invasive species can spread out of control for a number of reasons. Here are some examples:

• They don’t have any local predators because they were introduced from another location. They left their natural predators behind in their old environment.
• They have an adaptation that makes them stronger competitors, such as plants with toxic chemicals in their roots to kill other plants. Competition is an interaction between organisms or species in which the fitness of one is lowered by the presence of another.
• They have a very fast reproductive cycle that allows their population to grow rapidly.

When an invasive species takes over an area, it usually leaves little or no space for many of the native species that originally inhabited the area. One example is tree-of-heaven (Ailanthus altissima), which was introduced to the United States from China. Tree-of-heaven can grow in dense clusters and quickly outcompetes native trees. It can also take over fields and meadows quickly. When tree-of-heaven takes over, it reduces the variety of other plants growing in the area. Even though tree-of-heaven might produce shelter and food for some animals, it will take away food and shelter provided by the many other species that it has outcompeted. Most animals are specially adapted to their food and shelter sources. Eventually, the area taken over by tree-of-heaven will have not only fewer plant species but also fewer animal species.

The variety of different living things occupying a specific habitat or ecosystem (all of the living and nonliving things located in a given area) is referred to as the biodiversity of that place. Biodiversity is an important measure of a habitat or ecosystem because it contributes to the overall health of that area. A wide variety of species provides a complete food web, a multitude of habitat options, and even a system for moving important nutrients throughout the area. The fact that invasive species usually decrease the biodiversity of an area means that they create a negative impact on the overall health of an ecosystem.

Educational Objectives
This activity is designed to introduce the participants to the biodiversity of a study area close to their home or school. After exploring the study area, participants will be able to reflect on the variety of species found in their community and their relationship to one another, and they will be able to consider the impacts of an invasive species on ecosystem health.

Educational Standards Addressed
NGSS LS2.A: Interdependent Relationships in Ecosystems
LS2.B: Cycles of Matter and Energy Transfer in Ecosystems
LS2.C: Ecosystem Dynamics, Functioning, and Resilience

Vocabulary
Biodiversity
Competition
Ecosystem
Activity 1
A Tangled Web

**Time Required:** 20–25 minutes

**Materials Needed:** ball of string/yarn

To reinforce the importance of biodiversity, you might enjoy doing the following foodweb activity with a group of friends before getting to the main activity in this section.

Grab a ball of string, yarn, or rope and have everybody stand in a circle. Choose one person to start the activity and hand them the string; he or she will represent a “human.”

Ask the “human” to name one thing that he or she likes eat.

Now ask the group to come up with an example of another living thing that also eats that same thing. For example, if the “human” says he/she likes to eat carrots, then a horse might be another living thing that eats carrots.

Have the “human” hold on to the end of the string and unroll it until it reaches the first person to come up with an answer. The “human” and the “horse” (for example) are now connected across the circle by the string.

Now ask what other foods a horse eats (substitute “horse” with the living thing that was actually named during your activity).

An example might be that a horse eats grass.

Unroll the string to the first person to answer so three people are holding the string as it criss-crosses the circle. The third person would represent “grass.”

Continue this process until everyone is holding the string. You may alternate the question to either “What else do they eat?” or “What else eats that?” When talking about an animal, don’t be afraid to ask, “What eats that?” That way, you can introduce some carnivores in the mix. You can suggest vultures, fungi, flies, and bacteria if you get to a large carnivore that may not have any obvious predators.

Once everyone is holding the string, it should criss-cross the circle many times. Ask the participants to describe what it looks like. They have just formed a food web.

To emphasize the importance of all living things, choose one participant in the circle to go extinct. This activity has the most impact if you choose a living thing that the group is least likely to consider important (like a fly or grass).

Ask the extinct species to release his/her portion of the string. Now follow the loose string in each direction to the two species directly connected to the extinct species. Point out that without flies (or whatever you chose), those other two species are affected.

Have those two species let go of the string, too.

Continue to have each person let go of the string as the species to which they are connected also lets go.

What has happened to the food web? Take a moment to reflect on how all species are dependent on one another, and that having a wide variety of species is important to help keep our ecosystems strong.
Activity 2
Observing Biodiversity Outdoors

Time Required: 60–90 minutes

Materials Needed: record sheet copies (available to reproduce from the Appendix on page 45), clipboards, pencils, several hula hoops, butterfly nets, a white sheet or towel, magnifying glasses (optional)

Facilitator Note: When offered a choice, most youth will want to catch insects, not look at plants. Use the record sheets provided on clipboards to help youth with recording their observations. You may want to establish a timed rotation so that youth are encouraged to move through all of the planned observation sites.

Now that you have learned about the importance of biodiversity to our ecosystems, head outside and explore the biodiversity of your home, school, or community park.

Plants
When scientists want to know about the numbers of different plants growing in a specific location, they will typically explore “plots” of land instead of the whole area. Exploring the whole site usually takes way too much time.

Working individually or as a group, find an open area to explore as your study site (a field, meadow, lawn, or similar area). Toss a hula hoop gently out into your study site. Wherever your hula hoops lands will be your plot to study. Bring your hula hoop down to the ground and lay it flat if it got hung up on any taller plants.

Explore the plants growing in your plot (inside the boundaries of your hula hoop). You don’t need to be able to identify what types of plants they are—just notice all of the differences between them.

Complete your record sheet as you explore your plot.

Toss your hula hoop a few more times to explore at least two plots. Complete your record sheet as you go.

Plant Diversity Observations
Let’s compare the plots we looked at.
1. Which plot had the most diversity of plants (the highest number of different plants)? What was the number of plants found there?
2. Which plot had the least diversity of plants (the lowest number of different plants)? What was the number of plants found there?
3. Were there a lot of differences throughout your study site, or were most of the plots the same?
**Insects**
Some insects are really obvious and easy to see, like brightly colored butterflies. Others are harder to see, hiding under rocks or camouflaged into the scenery. Observing the biodiversity of insects in your study site will require a few different procedures. You may also find some things that look like insects but really are not (like centipedes and spiders). For this exercise, you can count them as well. We are going to rotate through four specific locations where we might find insects.

See what you can find. Take a walk around your study site and look for obvious insects on plants, in the air, and on the ground. Complete your record sheet for “Out in the Open.”

Look a little closer. Find rocks and logs in your study site that you can look underneath. Complete your record sheet for “Under Rocks and Logs.”

If you have tall grasses or meadow-like plants, use a butterfly net or a similar net to explore further. Sweep the net gently back and forth through the tall grasses. Check inside your net to see if you scooped up any insects hiding among the plants. Complete your record sheet for “In Tall Grasses.”

If you have small trees or shrubs, lay a white towel or sheet on the ground around and under your tree or shrub. Gently, yet firmly, shake or thump on the main stem/trunk of the tree or shrub ten times. The idea is to shake insects out of the branches without damaging the plant. Take a look at your white sheet and count the types of insects that you found. Complete your record sheet for “In Trees and Shrubs.”

**Insect Diversity Observations**
1. What was the total number of different insects that you found in each of the four study sites?
2. In which habitat did you find the most diversity of insects: out in the open, under rocks and logs, in tall grasses, or in trees and shrubs?

**Processing Questions**
1. Consider the plants and insects that you observed in your study site. How would you classify the biodiversity in your study site?
2. How would you compare the number of different plants you found to the number of different insects you found?
3. How might you use this information to determine the overall health of the ecosystem at your study site?
4. In what ways do plants need insects?
5. In what ways do insects need plants?
6. How might two different types of insects use the same plant differently?
7. What do you think would happen to the number of different insects in your study site if there was only one type of plant throughout your entire study site?
8. What do you think would happen to the number of different plants in your study site if there was only one type of insect?
9. How could an invasive species impact the overall health of an ecosystem?
10. Did you notice any invasive species that you’ve learned about in any of the locations?

**Reference**
USDA National Agriculture Library, National Invasive Species Information Center, Species Profiles—Tree-of-Heaven:  
[www.invasivespeciesinfo.gov/plants/treeheaven.shtml](http://www.invasivespeciesinfo.gov/plants/treeheaven.shtml)
Invasive Species Case Study

Feral Swine

**Biology**

**Important Biological Facts**

Like domestic hogs, feral swine can be of any color. Their size and conformation depend on their breed and the degree to which they have hybridized with the wild boar. Size also depends on their nutrition. Feral hogs have shorter legs, smaller heads, and shorter snouts than wild boars. Male feral hogs have continuously growing tusks, which they can use to defend themselves. They are considered intelligent animals and can readily adapt to changing conditions. They modify their response to humans rapidly if it benefits their survival. They usually feed at night.

**Food Source**

Feral swine will eat anything from grain to carrion. Acorns make up a good portion of their diet. In the winter, they eat underground vegetation and invertebrates. Feral swine have been known to prey on lambs, goat kids, calves, and exotic game.

**Life Cycle**

*(Stages of form and function the species passes through over time.)*

Given adequate nutrition, a feral swine population can double in a little as four months. Feral swine can breed as early as six months of age, and sows can produce two litters in a year, with young being born at any time of the year. The litter size

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**Invasive Species:** Feral Swine

**Scientific Name:** *Sus scrofa* Linnaeus

**Distribution**

In 2010, few feral swine were found in Pennsylvania. Most were found in Texas, California, and the southernmost parts of the United States. In 2015, established feral swine populations were recorded in southwestern Pennsylvania.
depends on the sow’s age and nutrition and the
time of year, but they average anywhere between
four and ten swine per litter.

Environment Needed to Thrive
Feral swine accept a variety of habitats. They pre-
fer the dense cover of brush or marsh vegetation.
They are generally restricted to areas below the
snow line and above freezing during the winter.
They like to visit livestock-producing areas, and
prefer hardwood forests.

Impact
(Explain the impact that this invasive species has
on the environment, agriculture, the economy,
health, safety, etc.)
Wild pigs can cause a lot of damage. They can
destroy crops and pastures by rooting or grubbing.
They can also damage farm ponds and watering
holes. At times, they become predators of domes-
tic livestock and wildlife. They also cause depre-
dation on certain forest tree seedlings, which is
detrimental to the forestry industry. Other areas
of damage have been reported in gardens, golf
courses, fences, and yards. They have been known
to transmit diseases to livestock, such as cholera,
swine brucellosis, trichinosis, bovine tuberculosis,
foot and mouth disease, and others.

Signs and Symptoms
(Describe the clues and indicators that this invasive
species shows when it is present in an environment.)
Rooting in wet or irrigated soil is generally visible
and can cover an area of several hundred square
feet or only a few small spots. Rooting can cause
destruction of crops and native plants, and lead
to soil erosion. Wallows are easy to see around
ponds and streams. Tracks of adult hogs look like
those made by a 200-pound calf.

Prevention
(How can the spread of this invasive species be
prevented?)
Some of the factors associated with the spread
of feral swine include the dispersal of feral swine
from outside populations, the escape or release
of domestic swine, or the transport and release
of feral swine. Controlling the introduction of
feral swine in the first place is the best method
of prevention. The spread of existing feral swine
can be prevented though fencing in small areas.
Heavy-gauge wire posts must be used. Feral
swine are not easily frightened, and there are
no known repellents or toxicants to keep them
out of areas. Cage traps and hunting are two of
the more effective ways to prevent the spread of
these animals and control populations. The cost to
completely exterminate feral swine in most areas
is very prohibitive, so long-term prevention plans
must be put into place.

Management
(How can damage that has already been caused
be reversed?)
It is difficult to reverse the damage caused by
feral swine. One of the best methods is to plant
regrowth in areas protected by fences and other
exclusion methods. Feral swine have a huge eco-
nomic impact for farmers and foresters in areas of
heavy swine populations.

References
Internet Center for Wildlife Damage Management, Wild Pigs: icwdm.org/handbook/mammals/wildpigs.asp
USDA National Agriculture Library, National Invasive Species Information Center, Species Profiles—Wild Boar:
www.invasivespeciesinfo.gov/animals/wildboar.shtml
You should now have a better understanding of how invasive species affect the Earth’s ecosystems. Remember:

- Most invasive species take over an ecosystem quickly and reduce the biodiversity of the ecosystem.
- Less biodiversity means there are fewer sources of food and shelter for living things to use.
- The overall health of an ecosystem goes down when biodiversity goes down.

When an invasive species takes over an area, it can also have a significant impact on the lives of the people living there. One example is the brown marmorated stink bug (*Halyomorpha halys*), which was introduced to the United States from the region around China and Japan. The stink bug first appeared in the United States in the 1990s. Because the stink bug is a very new species in the United States and Pennsylvania, it has no predators and populations can grow very fast.

Stink bugs have two very distinct impacts on people’s lives. First, stink bugs prefer warmer temperatures and move into people’s homes in large numbers in the winter. They are quite a nuisance and have a very unpleasant smell when crushed. Second, stink bugs have piercing mouth parts that are used to suck the juices out of plants. They prefer tree fruits like apples and peaches, among many other important crops. When they feed on these plants, they leave brown spots behind that make the fruits unsuitable for sale in most markets. In 2011, Mid-Atlantic farmers suffered more than $37 million in apple damages. Some people also suffer from allergies to stink bugs.

Like the stink bug, there are a number of other invasive plants and animals that lead to very expensive damages. These damages are referred to as the **economic impacts** of invasive species and include things such as:

- Damaging fruit and vegetable crops
- Clogging irrigation water pipes
- Damaging trees used for wood products
- Reducing populations of commercial fish
- Contaminating drinking water
- Taking over farm fields, lawns, and landscaping
- Spreading diseases in livestock

People are also affected personally by invasive species. Many invasive species, like the stink bug, become **nuisances** in people’s homes. Other invasive species reduce the enjoyment of outdoor recreational activities like swimming, fishing, boating, hiking, and hunting.
Activity 1

Out-of-Control Pests

Time Required: 45–60 minutes

Materials Needed: buckets and poker chips or similar small objects (see instructions for quantity based on the number of participants), flip-chart or whiteboard and markers, armbands or bandanas if desired, cones or chairs to mark playing field boundaries

Facilitator Note: It is critical to make sure students understand that this activity is a simulation, not a competition. The objective is for their actions to simulate those of pests and invasive species in an apple orchard. It is easier to distinguish the players in this activity if you label them. The farmer could wear a bandana or farmer’s hat. The beetles could have armbands or something similar.

Now that you have learned about the economic impacts of invasive species, find out how invasive pests can damage a crop much more than native pests (those that live in an area naturally) through this hands-on activity.

Round 1. Native Pest: The Apple Maggot

Show youth a picture of apple maggots or apple maggot damage. Apple maggots are a native pest that has a natural native predator, a beetle. For this activity, you will need a group of friends or classmates and a room in which you can walk quickly for at least 50 feet. A school gymnasium or outdoor area is suggested.

You’re going to create an orchard in your playing field by randomly setting out 5 to 10 buckets to represent trees (ideally, you will have at least one more bucket than one-quarter the total number of people in your group; for example, use 6 buckets if 20 people are completing the activity). You will also need apples in your orchard. You can use index cards, poker chips, or any other small object that is easy to grab out of your buckets. You will want 4 apples for each participant (for example, if 20 people are completing the activity, use 80 “apples”). Divide your apples up evenly, placing them in all of your buckets.

Choose one person to be the farmer. Divide the remaining participants into four groups. Three of the groups will be apple maggots (Rhagoletis pomonella), the larvae of a native fly that feed on the apples. The fourth group will be native beetles that feed on the apple maggots (the players in the other three groups).

The beetles and the farmer should spread out in the middle of the orchard. The apple maggots should all line up along the edge of the orchard to start the activity.

When the farmer says, “Start,” the apple maggots are going to try to get to the apples to feed on them. They will enter the orchard, take one apple from a tree (bucket), and then move on to collect an apple from another tree (only one apple can be collected from a tree at a time; apple maggots have to move on once they collect an apple). Apple maggots keep going until they have collected four apples, and then they leave the playing field.

The beetles are going to try to feed on the apple maggots by tagging them. Beetles will gently tag the apple maggots as they try to move through the orchard. If an apple maggot is tagged, it has been eaten, can no longer collect apples, and must leave the playing field, stepping off to the side of the orchard until the activity is complete. Apple maggots hold on to whatever apples they have already collected.

The farmer will try to eliminate pests in his orchard by also tagging the apple maggots as they move through the orchard. When a farmer tags an apple maggot, it has been killed by the farmer and can no longer collect apples. The apple maggot must leave the playing field, stepping off to the side of the orchard until the activity is complete. Apple maggots again hold on to whatever apples they have already collected.

Beetles and the farmer should be encouraged to work independently so that youth are not ganging up on single players.

After all apple maggots have left the orchard, having either been tagged or collected four apples, the activity stops.

Continued on next page
Use a flipchart or whiteboard to record the statistics below:

<table>
<thead>
<tr>
<th>Original Number of Apples on the Wall</th>
<th>Number of Apples Remaining on the Wall after the Activity</th>
<th>Number of Apples Fed on by the Native Pest, Apple Maggots</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

**Round 2. Invasive Pest: The Stink Bug**

Return all “apples” collected in the first round of the activity so that the apple orchard is full again.

Choose one person to be the farmer. This time, the remaining participants will all be stink bugs (*Halyomorpha halys*) (remember, invasive pests take over quickly and generally have large populations).

Stink bugs will try to feed on apples in the orchard by collecting them from the buckets. The farmer will try to stop the stink bugs by tagging them. Tagged stink bugs have been killed and must step out of the orchard until the activity ends. Stink bugs may feed on up to four apples, but they must move from tree to tree to collect each apple. The activity continues until all stink bugs have left the orchard, having been tagged or having fed on four apples.

There are no predators this time because stink bugs have no natural predators where we live.

Use a flipchart or whiteboard to record the statistics below:

<table>
<thead>
<tr>
<th>Original Number of Apples on the Wall</th>
<th>Number of Apples Remaining on the Wall after the Activity</th>
<th>Number of Apples Fed on by the Native Pest, Stink Bugs</th>
</tr>
</thead>
<tbody>
<tr>
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</tbody>
</table>

**Processing Questions**

1. Describe the outcome of the native pest (apple maggot) round of this activity.
2. Describe the outcome of the invasive pest (stink bug) round of this activity.
3. How were the apples affected differently by native and invasive pests?
4. How is the farmer affected differently by native and invasive pests?
5. In what ways might you be affected differently by these native and invasive pests?
6. Why would farmers be very concerned if they heard that a new invasive pest had been identified in their community?
7. How might farmers try to prevent an invasive pest from arriving at their farms?

**Variations**

It may be interesting to re-create this activity with both native and invasive apple pests attacking the orchard simultaneously. Try the activity with one farmer, one-quarter of the youth as beetles, and the remaining youth split into apple maggots and stink bugs (for example, with 20 youth it would be 1 farmer, 5 beetles, 7 apple maggots, 7 stink bugs). The farmer can tag all pests, but the beetles can only tag apple maggots. You will need to label the participants to prevent confusion. Try name tags or colored armbands.

Use a flipchart or whiteboard to record the statistics below:

<table>
<thead>
<tr>
<th>Original Number of Apples on the Wall</th>
<th>Number of Apples Remaining on the Wall after the Activity</th>
<th>Number of Apples Fed on by the Native Pest, Apple Maggots</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**References**

Penn State Department of Entomology, Insect Advice from Extension, Brown Marmorated Stink Bug:
[ento.psu.edu/extension/factsheets/brown-marmorated-stink-bug](ento.psu.edu/extension/factsheets/brown-marmorated-stink-bug)

Penn State Extension, Tree Fruit Production—Apple Maggot:
[extension.psu.edu/plants/tree-fruit/insects-mites/factsheets/apple-maggot](extension.psu.edu/plants/tree-fruit/insects-mites/factsheets/apple-maggot)

Invasive Species Case Study

Allium Leafminer

Invasive Species: Allium Leafminer (or Onion Leafminer)

Scientific Name: Phytomyza gymnostoma Loew

Distribution
The allium leafminer's first appearance in the United States was in 2015, in Lancaster County, where it was found infesting leeks and onions. The Pennsylvania Department of Agriculture reported that it since has been discovered in Lehigh, Chester, Dauphin, and Delaware Counties.

Biology

Important Biological Facts
The allium leafminer is an insect native to Germany and Poland. Its geographic range has been expanding rapidly, most likely as a hitchhiker on commercial cargo shipments and shipments of crop plants. It reached the United Kingdom in 2004 and has been reported in Asia, Turkey, and Russia as well.

Food Source
Adult allium leafminers feed on the fluids of onion family plants, including garlic, shallots, chives, ornamental species, and common weed onions in addition to cultivated onions. Leafminer larvae eat the plant tissue inside onion leaves.

Life Cycle
(Stages of form and function the species passes through over time.)
Allium leafminer adults are small, gray or mat-black-colored flies with a distinctive yellow or orange patch on the top and front and yellow on the side of the abdomen. They hold their wings horizontally over their abdomen when at rest. Their legs have distinctive yellow “knees.” Females lay eggs in the leaves of onion plants. The eggs hatch into larvae, which then pupate near the bulbs of the plants. There can be anywhere from 20 to 100 pupae per plant. The larvae are headless, white, cream, or yellowish maggots measuring up to 8 millimeters long at their final instar. The pupa stage is dark brown and 3.5 millimeters long.

Environment Needed to Thrive
Allium leafminers can overwinter as pupae in plant tissue or surrounding soil in a climate similar to that of Pennsylvania.

Continued on next page
Case Study: Allium Leafminer (continued)

**Impact**
(Explain the impact that this invasive species has on the environment, agriculture, the economy, health, safety, etc.)
Plant damage occurs when female leafminers make repeated punctures in leaf tissue with their ovipositors, and both females and males feed on the plant fluids. The larvae mine the leaves and move toward and into bulbs and leaf sheathes, where they pupate. Both the leaf punctures and mines serve as entry routes for bacterial and fungal pathogens. Organic and market-garden production systems and home gardens tend to experience the most damage. Because wild onion species exist as weeds in our region, this pest may have significant impacts on conventional growers as well.

**Signs and Symptoms**
(Describe the clues and indicators that this invasive species shows when it is present in an environment.)
Leaf punctures arranged in a linear pattern toward the distal end of leaves may be the first sign of damage. Leaves can be wavy, curled, and distorted.

**Prevention**
(How can the spread of this invasive species be prevented?)
Pennsylvania growers or home gardeners who are not in one of the five affected counties and think they might have observed damage or a life stage of the allium leafminer should contact a plant inspector in the regional Department of Agriculture office or the nearest Penn State Extension office.

**Management**
(How can damage that has already been caused be reversed?)
To monitor for allium leafminer, onion growers can use yellow sticky cards or yellow plastic bowls containing soapy water to capture adults. Starting in February and continuing through spring emergence of adults, excluding leafminers by covering plants may help protect crops. In addition, infestation rates can be reduced by delaying planting until late spring to avoid the adult egg-laying period. Covering fall plantings during the second-generation flight also can be effective.

**References**
Penn State Department of Entomology, Insect Advice from Extension, Pest Alert—Allium Leafminer: ento.psu.edu/extension/vegetables/pest-alert-allium-leafminer
CHAPTER 4
How Do Invasive Species Spread?

Invasive species enter a new location or spread throughout a location by three primary ways:

1. Travel by commercial shipments in airplanes, ships, and trains. Shipments of food and agricultural products are especially susceptible to accidental transport of invasive species in shipping containers.
2. People traveling to foreign countries. When travelers bring prohibited plants, seeds, fruits, animals, or other items back home, they risk bringing invasive species with them.
3. Hitchhiking. Invasive species are inadvertently transported on vehicles, boats, firewood, and even animals as they travel from one area to another.

The USDA refers to these sources of transportation and geographic spread as pest pathways. Refer to Vin Vasive’s “Top 8 Ways I Spread” infographic at HungryPests.com for a complete list of pest pathways. The life cycle and habits of an invasive species often determine which pathways contribute most to their geographical spread.

As ordinary citizens go about their everyday business, invasive species can hitchhike along with them and move geographically. One example of a hitchhiking invasive insect species is the spotted lanternfly (*Lycorma delicatula*). People can accidentally transport the spotted lanternfly as a result of camping in the woods. Spotted lanternfly eggs are well camouflaged and require diligent inspection in order to prevent them from spreading. They can be found on firewood, tarps, and any outdoor equipment. Camping equipment is particularly important to check because it is frequently moved from one campground to the next and could carry the egg masses to new locations. When the spotted lanternfly does spread, it causes significant damage to nearby farms growing grapes, apples, other fruits, and hardwood trees.

Educational Objectives
Using the thorough understanding of what invasive species are and their impacts on our environment and economy, participants will now develop an understanding of how populations of invasive species are introduced and how they spread geographically.

Educational Standards Addressed
NGSS ESS3.C: Human Impacts on Earth Systems

Vocabulary
Hitchhiking
Pest pathways
Activity 1
Hitchhikers

Time Required: 30 minutes

Materials Needed: small mat or rug, two black poster boards, Glo Germ™ powder or other glow-in-the-dark powder and a UV light, camping gear props for each participant (backpacks, tackle boxes, cinched sleeping bags, etc.)

Facilitator Note: Be careful to spread only a small amount of Glo Germ™ powder on the small mat. If you spread too much, the powder is visible without the black light. Make sure the students do not accidentally “re-infest” the sites by stepping on the black poster boards while trying to see the results.

Let’s explore how outdoor gear serves as a pathway to spreading an invasive species.

Spread Glo Germ™ powder on a small mat in one corner of the room. This corner of the room will represent a campsite in the forest and the Glo Germ™ will represent an invasive species at that campsite. A forest campsite was the geographic location of the initial sighting of the spotted lanternfly in the United States, discovered in Pennsylvania in 2014.

Place two pieces of black poster board in two other corners of the room or play area. Those corners will represent campsites at two other parks.

Divide all the participants into two groups of “campers.” Send one group of campers to the mat campsite, where the spotted lanternfly is already found. Send the other to group of campers to one of the black poster board campsites.

All of the campers will walk around their campsites and through the forest at their site, dragging their feet and camping/fishing gear (e.g., a cinch sack and tackle box) on the mat/poster board. They have been camping at their site for several days and are not being careful about checking their gear for hitchhikers.

Now the campers in the mat corner, where the spotted lanternfly lives, pack up their gear and meet up with the second group of campers at their park. They walk on the poster board and drop/drag their gear. Because they weren’t careful, they have likely brought the spotted lanternfly eggs with them to this new campsite, introducing an invasive species there.

The second group of campers already camping at that park continues to travel through their campsite, dragging their feet and gear across the black poster board, with their friends in the first group of campers.

The second group of campers now packs up their gear and travels to a third park at the remaining black poster board, dragging and dropping their gear. This group of campers is continuing to spread the spotted lanternfly eggs, introducing an invasive species at yet another campsite.

Finish this role-playing activity by having the initial group of campers travel to the last campsite.

Shine the black light on all of the black poster boards to see how much the spotted lanternfly has spread. Review how many new places this invasive species was introduced.

Processing Questions
1. Have you ever taken a hike in a state or national park?
2. Did you ever consider whether you were carrying any hitchhikers with you?
3. Have you ever gone camping? Where did the firewood you used for your campfire come from?
4. Have you ever traveled to a foreign country? Did customs officers ask you questions about food, plants, and agricultural products when you returned?
5. Do you live near a shipping port, airport, or train station?

Reference
USDA Animal and Plant Health Inspection Service (APHIS), HungryPests.com
Invasive Species Case Study
Hydrilla

Invasive Species: Hydrilla

Scientific Name: *Hydrilla verticillata*

Distribution
Hydrilla is found in lakes and streams in many portions of Pennsylvania. It is most prevalent in the east, and south-central portions of the state.

Biology

Important Biological Facts
Hydrilla is an aquatic plant that is rooted in the bottom of lakes and streams. It has stems and leaves that form dense mats near the surface when the water is still or slow moving. The stems can be many feet long depending on the depth of the water. Hydrilla leaves are narrow, have teeth, and are arranged in groups of four to eight in whorls around the stem. It was introduced to the United States from Asia as an aquarium plant.

Food Source
Like all plants, hydrilla makes its own food through photosynthesis. Depending on how clear the water is, which determines if sunlight can reach the leaves, hydrilla can live in water up to 12 feet deep.

Life Cycle
*(Stages of form and function the species passes through over time.)*
Hydrilla produces flowers that become seeds when pollinated. In Pennsylvania, however, most new hydrilla plants form from pieces of the plant that break off and grow new roots, forming a new colony. This is called vegetative propagation. Hydrilla also has long underground stems that will give rise to new plants, expanding an existing colony.

Environment Needed to Thrive
Hydrilla is tolerant of a variety of common water pollutants and can live in water with a wide range of pH, nutrient levels, and other chemistry.

Impact
*(Explain the impact that this invasive species has on the environment, agriculture, the economy, health, safety, etc.)*
Each year, millions of dollars are spent trying to control hydrilla. The dense mats formed by hydrilla clog the intake pipes of irrigation systems and hydroelectric plants. They also interfere with the

Continued on next page
navigation of both commercial and recreational boats. Hydrilla also outcompetes many native aquatic plant species. Hydrilla is classified as a noxious weed by the federal government.

**Signs and Symptoms**
(Describe the clues and indicators that this invasive species shows when it is present in an environment.)
Hydrilla is most obvious in the environment when it is in the form of thick, intertwined mats of leaves and stems. Boaters will notice hydrilla getting tangled on their propellers and will have to stop frequently to clean it off. There are several similar species of native waterweeds, but hydrilla is the only one with toothed leaves that feel rough to the touch.

**Prevention**
(How can the spread of this invasive species be prevented?)
Boaters, fishermen, and other water users should be extra careful to clean all plants and mud from their equipment before leaving a body of water. They should also remove all water from their equipment before they leave the site. When travelling between bodies of water, all equipment should be carefully washed and allowed to dry for several days before entering a new body of water. It is illegal to possess or transport hydrilla in Pennsylvania.

**Management**
(How can damage that has already been caused be reversed?)
Because pieces of stem can break off and grow into new plants, mechanical removal of hydrilla is not very effective. There are some chemicals that are moderately successful as herbicides. Some fish and insects also can help control hydrilla, but they must be carefully introduced so they don’t become nuisance species, too.

**References**
Penn State Extension Master Gardeners of York County, Aquatic Invasive Species: extension.psu.edu/plants/master-gardener/counties/york/pest-pages/aquatic-invasive-species
Pennsylvania Sea Grant, Hydrilla (Hydrilla verticillata): seagrant.psu.edu/sites/default/files/hydrilla2013_reduced_0.pdf
University of Florida, Institute of Food and Agricultural Sciences, Center for Aquatic and Invasive Plants, Hydrilla verticillata: plants.ifas.ufl.edu/node/183
CHAPTER 5

How Do We Prevent the Spread of Invasive Species?

Now that we understand how invasive species spread and the effects they have when they do spread, let’s learn about how we can better control invasive species. Ideally, the best possible outcome of any control would be to eradicate, or completely remove, an invasive species from an area where it has been introduced. Most often, invasive species controls are geared more toward slowing and stopping their spread instead. The USDA has identified seven key things that individuals can do to help prevent the spread of invasive species:

1. Buy and burn local firewood when camping.
2. Plant your gardens and landscapes carefully, and avoid plant species that could bring invasive species into your state.
3. Don’t bring or mail fresh fruits, vegetables, or plants into your state unless agricultural inspectors have cleared them.
4. Cooperate with agricultural quarantines, which restrict the movement of certain plants and animals that could become harmful invasive species.
5. Wash your outdoor gear between fishing, hunting, or camping trips.
6. Learn to identify invasive species. Participate in invasive species surveillance: if you see signs of an invasive pest or disease, write it down or take a photo and report it to USDA (www.aphis.usda.gov).
7. Speak up when returning from international travel and tell customs and border protection officials if you are carrying any agricultural items or food.

One example of an invasive species that could be controlled by your efforts—and by all people, not just scientists—is purple loosestrife (Lythrum salicaria). Purple loosestrife is a plant that grows in wetlands and has showy purple flowers. When it first arrived in the United States as a medicinal herb and in ship ballast water, it was prized for its beauty. It quickly spread from seed found in mud that traveled in on cars, boats, and other vehicles and through garden centers selling the plant as a horticultural variety, among other ways. Today, purple loosestrife is found throughout the United States, taking over wetland habitats and impeding the flow of irrigation waters. Two ways that people help control the spread of this invasive species are by cleaning mud off outdoor gear and vehicles after visiting a wetland and not intentionally planting purple loosestrife in their own gardens. Purple loosestrife is still sold at garden centers in many parts of the United States.

Educational Objectives
Using knowledge of how invasive species spread through pest pathways, participants will begin to appreciate the role they can play in preventing the spread of invasive species.

Educational Standards Addressed
NGSS ESS3.C: Human Impacts on Earth Systems
LS2.C: Ecosystem Dynamics, Functioning, and Resilience

Vocabulary
Eradicate
Quarantine
Surveillance
Activity 1
Tag! You Have Been Eradicated
Adapted from USDA HungryPests.com, resources for educators, Hungry Pests Summer Camp Activities.

**Time Required:** 30–60 minutes

**Materials Needed:** two different colored bandanas or armbands (enough for everyone to have one), photos of pest pathways (available to reproduce from the Appendix on page 48) or actual objects to represent them, and invasive species cards (adaptation cards from activity 1)

**Facilitator Note:** It is important to remind youth that this game is a simulation of how invasive species spread via pest pathways, not a competition. If running is not an option in your activity space, you could instead allow one team to walk normally, while the other has to walk backward or crawl (provided there are no obstacles in the playing field that would make this dangerous).

Invasive Species team members should select an invasive species card to identify what kind of pest they are. Invasive Species must carry their invasive species card with them and will move throughout the playing field, continuing from pathway to pathway throughout the game. USDA Agents must also keep moving from pathway to pathway throughout the game. The USDA Agents try to tag the Invasive Species to eradicate them before they reach a pest pathway. If tagged, the Invasive Species hands his/her card to the USDA Agent and leaves the playing field. When an Invasive Species reaches a pest pathway, he/she is safe. When a USDA Agent collects three invasive species cards, that agent can remove one pest pathway from the field. Any Invasive Species currently on that pest pathway will be vulnerable to easy tagging by a USDA Agent. The game ends when all the Invasive Species have been eradicated or all the pest pathways have been eliminated.

Play the game in two rounds. In the first round, the USDA Agents work at a leisurely pace and can only walk slowly around the playing field. In the second round, the USDA Agents are allowed to run/walk quickly to show how much better they can eliminate an invasive species if they work harder and faster.

Place pest pathway items or pictures around your playing field. Before play starts, ask the participants to identify all of the pest pathways on the playing field. If indoors, place the photo signs on tables or chairs. If outdoors, place them on the ground inside hula hoops to create “safe bases.” Divide participants into two teams, Invasive Species and USDA Agents, with roughly two-thirds of the group assigned to the Invasive Species team to start the first round.
Variations
When the number of Invasive Species has been reduced by 50 percent (half), begin eliminating USDA Agents. After all, when an invasive species is eradicated, the USDA staff people working on that project are redirected to other tasks.
If the group is large enough, have one-half of the invasive species stand on the sidelines and introduce them later, after half of the initial invasive species on the playing field have been eliminated.
Assign USDA Agents to defend against a particular Invasive Species. Sometimes we initially don’t assign enough people to address a problem.

Processing Questions
1. How many Invasive Species did we start with? End with? Is it truly possible to completely eradicate invasive species? (Pennsylvania did successfully eradicate the plum pox virus and is hoping to do the same with the spotted lanternfly.)
2. How did requiring the USDA Agents to walk while the Invasive Species ran change the game? Some invasive species travel and reproduce quickly. What does that tell us about the operation of eradication programs?
3. How did requiring the Invasive Species to walk while the USDA Agents ran affect the outcome? Do we solve problems faster when we all work together quickly?
4. How did removing pest pathways affect the speed with which the Invasive Species were eliminated?
5. Is removing pest pathways realistic? What is the real-world equivalent to the removal of pest pathways?
6. The USDA Agents are ordinary citizens just like you. What steps can you take, as an ordinary citizen, to eradicate invasive species?
7. We had a specific playing field for the game. How is that similar and different from a quarantine area?

If you tried any of the variations:
8. How did introducing new Invasive Species in the middle of the game affect the outcome? How did the USDA Agents react?
9. How did limiting which Invasive Species the USDA Agents could tag affect the outcome?
10. How did reducing the number of USDA Agents in the field/on the playing field affect the outcome?

Reference
USDA, Hungry Pests Invade Middle School, Lesson 4: Leaving Hungry Pests Behind: HungryPests.com
Invasive Species Case Study

**Spotted Lanternfly**

**Food Source**
Spotted lanternfly nymphs feed on the stems and bark of woody and nonwoody plants. Adults prefer tree-of-heaven (*Ailanthus altissima*), which is also an invasive species. Spotted lanternfly is known to attack more than 70 species of plants in Korea, 25 of which grow in Pennsylvania. These include grape vines, apple trees, and pine trees.

**Life Cycle**
(Stages of form and function the species passes through over time.)
In late April and early May, nymphs hatch from egg masses that overwintered on smooth bark, stone, and other vertical surfaces. They grow through four stages as nymphs, also called instars. The first-instar nymph is black with white spots and no wings. As it matures, red patches also develop. Adults are 1 inch long and emerge in mid-July with a black head and grayish wings with black spots. Egg laying begins in the fall and continues through December.

**Environment Needed to Thrive**
Spotted lanternfly lives in woody areas as well as fruit tree orchards and vineyards where access to food sources is plentiful.

**Impact**
(Explain the impact that this invasive species has on the environment, agriculture, the economy, health, safety, etc.)
The spotted lanternfly causes damage to growing plants and has the potential to greatly impact the grape, tree fruit, plant nursery, and timber indus-
tries. In Pennsylvania, this pest threatens the $20.5 million grape, $134 million apple, and $24 million stone fruit (like peaches and plums) industries. The hardwood industry, which accounts for $12 billion in sales, is also at risk.

Signs and Symptoms
(Describe the clues and indicators that this invasive species shows when it is present in an environment.)
Egg masses appear in rows and have a grayish covering that resembles tree bark. Adults congregate in groups of 4 to 18 or more in leaf litter near the tree base. Feeding creates weeping wounds in bark. Feeding damage also attracts ants, yellow jackets, and hornets.

Prevention
(How can the spread of this invasive species be prevented?)
Accidental transport of egg masses is the greatest risk for spreading spotted lanternfly. Before transporting items out of the quarantine area, citizens should carefully inspect items such as trailers, lumber, lawn furniture, landscaping materials and plants, camping equipment, and even recreational vehicles for egg masses.

Management
(How can damage that has already been caused be reversed?)
Eradication of this pest is the goal. Egg mass scraping and tree banding are decreasing the size of the current population. Research is being conducted to determine what else can be done to eliminate this pest. To prevent any further spread of the spotted lanternfly, a quarantine area was created to restrict the movement of materials that may harbor egg masses. Citizens can assist in scraping egg masses from trees and flat surfaces and destroying the eggs by double-bagging them and throwing them away. Brown sticky tree bands are an effective way to catch nymphs. Volunteers can assist in banding trees in the quarantine area.

References
Pennsylvania Department of Agriculture, Plant Industry—Spotted Lanternfly:
www.agriculture.pa.gov/Protect/PlantIndustry/spotted_lanternfly/Pages/default.aspx#.VfwZhk2FM5s
Penn State Extension, Pest Management—Spotted Lanternfly:
extension.psu.edu/pests/spotted-lanternfly
Invasive Species Case Study

Yellow Fever Mosquito and Asian Tiger Mosquito

Invasive Species: Yellow Fever Mosquito and Asian Tiger Mosquito

Scientific Names: Aedes aegypti and Aedes albopictus

Distribution
The yellow fever mosquito originated in Africa, but it has been in the United States for several centuries, causing historical outbreaks of yellow fever during the Spanish-American War (1898). It is now found across the southern United States and estimated to be living as far north as the southeastern corner of Pennsylvania and all of New Jersey.

The Asian tiger mosquito did not arrive in the continental United States until 1985. Its current distribution is estimated to include almost all of the eastern half of the country except the farthest north regions (i.e., Maine, Wisconsin). This includes the entire state of Pennsylvania.

Biology

Important Biological Facts
The yellow fever mosquito used to be much more common, especially in Florida, until the introduction of the Asian tiger mosquito. The Asian tiger mosquito outcompetes the yellow fever mosquito for food while in their larval stage. The Asian tiger mosquito also grows faster. Both mosquitoes can carry very serious diseases that can be transmitted to other animals, including humans. Both of these mosquitoes came to the United States through international shipping and transport. The Asian tiger mosquito is thought to have specifically come
here on shipments of used tires imported from Asia for use in recycled rubber products.

**Food Source**
Adult mosquitoes feed on nectar from flowers and juices from berries and other fruits. Only adult females feed on blood, and they use it to nourish and develop their eggs. Mosquito larvae live in the water and feed on small decaying debris and microorganisms floating in the water around them. Larger mosquito larvae will cannibalize smaller mosquito larvae as well.

**Lifecycle**
Mosquitoes have a life cycle similar to that of butterflies. They start out as eggs, which hatch into larvae, eventually form into pupae, and then emerge as flying adults. Mosquitoes lay their eggs in water, and they are very small, rarely noticed by humans. Mosquito larvae hatch from the eggs and live in the same water. The larvae feed and grow as much as they can because once they are adults, they can no longer grow in size. Eventually, the larvae become pupae, which continue to swim in the water. After a few days, the adult mosquito will emerge from the pupa, stand on the floating shell left behind to dry out, and then fly away.

**Environment Needed to Thrive**
Mosquitoes can lay their eggs in a body of water as small as a coffee cup. They take advantage of any and all bodies of standing water, including old tires filled with rain or a hole in a tree.

They thrive in human-made containers like trash piles, clogged gutters, bird baths, and flower pots because they have few or no predators living there with them. Both species of mosquitoes come from tropical parts of the world and thrive in similar habitats. The Asian tiger mosquito has adapted to live in cooler temperatures, which has extended its range.

**Impact**
*Explain the impact that this invasive species has on the environment, agriculture, the economy, health, safety, etc.*
While itchy bumps from mosquito bites are a nuisance, the true impact of the Asian tiger mosquito and the yellow fever mosquito are their ability to transmit serious diseases. These two mosquitoes act as vectors for several serious viruses. A vector is an organism that transmits a disease from one living thing to another. Both the yellow fever mosquito and the Asian tiger mosquito can transmit the deadly viruses yellow fever, dengue, and chikungunya. The yellow fever mosquito also transmits Zika virus, which was first diagnosed in the United States in 2016. The Asian tiger mosquito also transmits West Nile encephalitis, which was first identified in the United States in 1999. In addition to transmitting diseases in humans, the Asian tiger mosquito is also known to transmit diseases to livestock and pets. West Nile virus can be fatal to horses and exotic birds. This mosquito is also a vector for dog heartworm disease.
Case Study: Yellow Fever Mosquito and Asian Tiger Mosquito (continued)

Signs and Symptoms
(Describe the clues and indicators that this invasive species shows when it is present in an environment.)
While it’s not easy to identify specific types of mosquitoes without professional training, knowing the general signs and symptoms of all mosquitoes can help prevent the spread of these invasive species of mosquitoes and the diseases they carry. Standing bodies of water that have mosquito larvae and pupae living in them will often have a dotted surface where the insects are hanging out just below. The bite of a mosquito is a familiar sensation for most people. However, it can be easily confused with other insect bites as well. The female adult mosquito usually feeds in early morning or late afternoon and evening. The Asian tiger mosquito frequently prefers to feed on lower legs. The itchy, red reaction to the bite can appear almost immediately and last for several days.

Prevention
(How can the spread of this invasive species be prevented?)
Removing breeding sites for mosquitoes is the key to controlling these invasive species and their diseases. Make sure there is no standing water in containers, trash, gutters, or sewer drains on your property. If you use rain barrels or other water-collection tanks, make sure they have screens or covers that exclude mosquitoes. Change the water weekly in bird baths or children’s wading pools, maintain chlorine levels in swimming pools, keep fountains running or drain them when not in use, and stock pond gardens with mosquito-eating fish. Tablets, known as “dunks,” that contain an insecticide that will kill the larvae are also available for water tanks. State and local government agencies also participate in monitoring and spraying programs across the country.

Management
(How can damage that has already been caused be reversed?)
Management strategies for mosquitoes are very similar to the prevention methods listed above. If you already have mosquitoes on your property, you can reduce their populations by preventing new larvae from breeding. Larger bodies of water may be stocked with mosquitofish and cannibal mosquito larva. However, this is not practical for the most common breeding grounds found at most homes.

References
Center for Invasive Species and Ecosystem Health: invasives.org
Centers for Disease Control and Prevention, Chikungunya Virus: Surveillance and Control of Aedes aegypti and Aedes albopictus in the United States: www.cdc.gov/chikungunya/resources/vector-control.html
Penn State Extension, West Nile Virus: extension.psu.edu/pests/pesticide-education/applicators/pest-management/wnv
University of Florida, Featured Creatures: Yellow Fever Mosquito: entnemdept.ufl.edu/creatures/aquatic/aedes_aegypti.htm
USDA National Invasive Species Center, Asian Tiger Mosquito: www.invasivespeciesinfo.gov/animals/asiantigmos.shtml
CHAPTER 6
Invasive Species Case Study

A case study is a research method that involves the detailed examination of a topic. Case studies are used in a variety of scientific disciplines and can be used to analyze many different things. In this case study, an invasive species will be analyzed. You can use the Internet, the library, and other sources of information to help you with your case study. Here are some websites that might help get you started:

- Pennsylvania Department of Natural Resources, Invasive Species in Pennsylvania: www.dcnr.state.pa.us/conservationscience/invasivespecies/index.htm
- Pennsylvania Fish and Boat Commission, Aquatic Invasive Species: www.fishandboat.com/ais.htm
- Pennsylvania Invasive Species Council, Species Profiles—Insects and Other Invertebrates: invasivespeciescouncil.com/Profiles_Insects.aspx
- USDA National Agriculture Library, National Invasive Species Information Center, State Resources—Pennsylvania: www.invasivespeciesinfo.gov/unitedstates/pa.shtml

You can use the Internet resources above to find complete lists of invasive species. Several invasive species have also been introduced throughout the lessons in this series. If you take a look back at your favorite activities, you might be reminded of an invasive species that you would like to learn more about—just don’t choose one of the three species with case studies already completed in this book.

One more invasive species you might consider is the zebra mussel (Dreissena polymorpha). Zebra mussels came to the United States from eastern Europe in the ballast water of ships crossing the ocean. They were introduced to the Great Lakes region in the 1980s, and by 1990 they had infested all of the Great Lakes. Now they are found in 29 states as well. Zebra mussels not only compete with the native species living in fresh water, but they also clog pipes used for agriculture irrigation, water treatment, and more. There have been no successful methods to eliminate zebra mussels once they have established themselves. The spread of zebra mussels to new waters can be controlled, however, by carefully cleaning boats before moving them to new bodies of water. One unique fact about zebra mussels is that they have been helpful in reducing pollution and harmful algal blooms due to their filtering lifestyle. Maybe you can find a unique fact about your invasive species to include in your case study?

Educational Objectives
Participants will become familiar with one specific invasive species through guided research and gain a well-rounded knowledge of that invasive species.

Participants will gain experience using a variety of resources to collect scientific information on a specific invasive species of their choice and use this information to answer questions and practice solving problems.

Educational Standards Addressed
WHST.6-8.1: Cite specific textual evidence to support analysis of science and technical texts. (MS-LS1-3)

WHST.6-8.7: Conduct short research projects to answer a question (including a self-generated question) drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration. (MS-LS1-1)

WHST.6-8.8: Gather relevant information from multiple print and digital sources using search terms effectively, assess the credibility and accuracy of each source, and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation. (MS-LS1-8)

Vocabulary
Life cycle
Management
Signs and symptoms
Activity 1
Complete Your Own Case Study

Time Required: 60–90 minutes

Materials Needed: access to research materials (Internet, library, etc.), pencils and paper, copies of the case study worksheet (provided in this publication), access to pictures to print or cut out

Choose an invasive species and use the following worksheet to carry out your case study. Here are a few tips to remember when you are doing research:
- Research can be collected from a variety of different sources, including websites, scientific journals, nonfiction books, and magazines. Remember to cite the resources you use. It is important to give credit to the individuals who make this information available for us.
- Collect your information from a variety of different sites and resources. Researching from a variety of places will allow you to collect more information and double-check its accuracy. Make sure to write your final report in your own words.
- Check for correct grammar and spelling, and use complete sentences when explaining something. It is important to proofread your work before releasing it for review. Scientists are commonly evaluated on how well they can write and express themselves.

Processing Questions
1. Describe the adaptation that makes your case study invasive species thrive in new environments.
2. Explain how this invasive species is detrimental to the environment, agriculture, and economy.
3. What are some ways that the spread of this invasive species can be controlled? What can you do personally to help in this effort?
4. How could the introduction of this invasive species have been prevented?

Reference
**Invasive Species Case Study**

**Invasive Species:**

**Scientific Name:**

**Distribution**
*Where in Pennsylvania is this invasive species found?*

**Biology**
*Important Biological Facts*

**Food Source**

**Life Cycle**
*Stages of form and function the species passes through over time.*

**Environment Needed to Thrive**

Insert a picture of the invasive species here.

Insert pictures of the invasive species’ food, life cycle, and/or environmental needs.

Insert pictures of the invasive species’ food, life cycle, and/or environmental needs.

Insert pictures of the invasive species’ food, life cycle, and/or environmental needs.
### Impact
*Explain the impact that this invasive species has on the environment, agriculture, the economy, health, safety, etc.*

### Signs and Symptoms
*Describe the clues and indicators that this invasive species shows when it is present in an environment.*

### Prevention
*How can the spread of this invasive species be prevented?*

### Management
*How can damage that has already been caused be reversed?*

### References
Adaptation: A trait that has evolved and is maintained in a species due to its functional role in the life of the members of that species.

Biodiversity: The variety and variability of living things in a particular region or ecosystem.

Competition: The efforts of two or more living things or species that are trying to succeed against each other to use a limited resource.

Dispersal: The movement of living things from one area (where they are born) to another (where they breed).

Ecological competence: The ability of a living thing to compete and survive in a new habitat.

Economic impacts: The effect that something has (like an invasive species) on factors related to the financial costs to humans.

Ecosystem: A system formed by all of the living things and their interactions with the nonliving environment in a specific area or region.

Eradicate: To completely eliminate something (e.g., the complete removal of an invasive species from a region or ecosystem).

Generalist: A species that is able to thrive in a wide variety of habitats and make use of lots of different resources for food and shelter.

Hitchhiking: A pest pathway where a living thing attaches to a vehicle, shipping crate, another living thing, or any other object and moves along with it to get to new places.

Invasive species: A living thing that is nonnative (or alien) to an ecosystem and whose introduction causes or is likely to cause harm to the economy, the environment, or human health.

Life cycle: The life stages that a living things goes through from birth to reproduction and generating new offspring.

Management: Planning for and implementing plans to control the spread and reduce the impacts of invasive species.

Native species: A living thing that has been part of a particular region or ecosystem for hundreds or thousands of years and is part of the balance of nature there.

Nonnative species: A living thing that has been introduced, with human help, to a new place or new type of habitat; also referred to as “alien” species.

Nuisance: Something that is annoying or causes trouble and/or problems.

Pest pathways: The different ways that new invasive species are introduced.

Phenotypic plasticity: The ability of a living thing to change its appearance, behavior, and other characteristics in response to changes in the environment around it.

Quarantine: Separating or restricting the movement of certain things; when a threat exists, it is used to prevent the possible movement of an invasive species to a new place.

Signs and symptoms: Evidence of something (e.g., the occurrence of an invasive species in a region or ecosystem); may include tracks and scat, destruction of property, egg cases, etc.

Surveillance: Monitoring and keeping a close eye out for something such as an invasive species that may be moving into new areas.
Appendix

Chapter 1, Activity 1
*Meet the Invasive Species*
  Pennsylvania Invasive Species Cards . . . . . . . . . . . . . . . 39

Chapter 2, Activity 2
*Observing Biodiversity Outdoors*
  Record Sheets . . . . . . . . . . . . . . . . . . . . . . . . . . . . 45

Chapter 5, Activity 1
(Tag! You Have Been Eradicated)
  Invasive Species Pest Pathways Photo Sheets . . . . . . . . . . 48
Spotted Lanternfly

The spotted lanternfly lays egg masses of 30 to 50 eggs wherever there’s a flat surface—meaning that many household items frequently left outdoors and transported can carry this pest along when moved, helping it spread quickly. The adult lanternflies cause significant damage to fruit trees and other hardwoods.

Photos: Holly Raguza

Asian Longhorned Beetle

In the early stage of their life cycle, the white wormlike beetle larvae bore into live trees, causing sap to flow from wounds and frass (sawdust and other insect waste) to accumulate at tree bases. Left undetected, this insect will cut off the vascular system of trees, eventually causing the tree to wither and die. The beetle has no natural predators in Pennsylvania.

Photos: Buster&Bubby

Zebra Mussel

These freshwater mussels colonize hard surfaces. They are highly efficient filter feeders, removing phytoplankton from the water and starving other plankton-eating animals. They reproduce quickly and can spread easily in small amounts of water.

Photo: Neil DeMaster (large image), John Carl (small image)

Hydrilla

Hydrilla is a plant that grows quickly in aquatic environments. It forms dense mats and interferes with boat motors, irrigation, and hydroelectric water intakes. The dense mats prevent sunlight from penetrating, which shades desirable plants growing underneath. Blooms of this plant that die in a pond can consume all the oxygen, causing a fish kill.

Photo: Chuck Sutherland
**House Mouse**
The house mouse has been able to colonize habitats normally considered inhospitable because it has a high reproductive rate and the ability to migrate. It is also able to take advantage of temporary habitats, such as cultivated fields. Females can mate within 12 to 18 hours after giving birth, and will bear 5 to 10 litters per year if conditions are right. These mice are able to squeeze through gaps slightly wider than ¼ inch, and they are also excellent climbers, scaling rough vertical walls and pipes.

Photo: Christophre Campbell

**Feral Swine**
Feral pigs are much more destructive than domesticated pigs. They were brought to the United States as domestic pigs from Europe and Asia and have escaped into the wild. They can produce four to eight babies per litter. Feral swine are highly adaptable, but they prefer habitats with an abundant supply of water and dense cover. They are aggressive and pose serious ecological, economic, and health threats.

Photo: Dana Johnson

**Common Carp**
The common carp’s feeding habits of grubbing on the bottom of water bodies disrupts shallow-rooted plants and muddies the water. They release phosphorus, which increases algae growth, making the water uninhabitable for some native fish and organisms. In addition, their high reproduction rates allow them to outcompete many native fish species.

Photo: Joeke Pieters

**Northern Snakehead**
Northern snakeheads are predatory fish that can potentially devastate native fish and wildlife populations. Young snakeheads eat zooplankton, insect and fish larvae, and small crustaceans. Frogs, fish, crustaceans, small reptiles, and even small birds and mammals are taken by adults. Nicknamed “frankenfish,” they tolerate poor water conditions and can actually move over land for short distances.

Photo: U.S. Geological Survey
**Japanese Stiltgrass**

Japanese stiltgrass is able to grow in a wide range of habitats. After disturbance, Japanese stiltgrass readily takes advantage of shaded areas, but it likes sunlight, too. Disturbances such as floods, use of heavy equipment (especially logging), tilling, mowing, construction activities, and heavy animal impact all increase opportunities for stiltgrass to take over. Seeds can be created without pollination if the conditions are right. Individual plants can produce between 100 and 1,000 seeds.

Photo: mightyjoepye

**Garlic Mustard**

Once introduced to an area, garlic mustard outcompetes native plants by monopolizing light, moisture, nutrients, soil, and space. Garlic mustard is not consumed by our local wildlife. Native wildflowers that complete their life cycles in the spring are frequently outcompeted by garlic mustard.

Photo: hspauldi

**Hemlock Woolly Adelgid**

The hemlock woolly adelgid feeds on the sap of tender hemlock shoots. It may also inject a toxin while feeding. This causes the tree to lose needles and not produce new growth. Trees that survive the direct effects of the infection are usually weakened and may die from secondary causes. This insect can reproduce twice per year and spread without any assistance.

Photo: Dennis J. Souto

**Stink Bug**

Stink bugs were first discovered in the United States in Pennsylvania during the late 1990s. No one knows for certain how they were introduced to North America. Brown marmorated stink bug populations are exploding because they do not have any natural predators in Pennsylvania. The odor they release when crushed makes them unappealing to predators. Stink bugs have piercing mouth parts that damage apples, peaches, and other crops.

Photo: Jacinta Iluch Valero
**Record Sheets for Activity 2**

**Observing Biodiversity Outdoors**

**Plants**

**Plot 1:** Toss your hula hoop gently into your study site to identify your plot. Draw or describe the different plants you see.

<table>
<thead>
<tr>
<th>Draw or describe the plants.</th>
<th>How many did you see? What was their prevalence?</th>
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How many different plants did you find? __________________

Is there one plant that seems to take up most of the space in your plot? __________________

**Plot 2:** Again, toss your hula hoop gently into your study site to identify a new plot. Draw or describe the different plants you see.

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<thead>
<tr>
<th>Draw or describe the plants.</th>
<th>How many did you see? What was their prevalence?</th>
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How many different plants did you find? __________________

Is there one plant that seems to take up most of the space in your plot? __________________
Record Sheets for Activity 2
Observe Biodiversity Outdoors (continued)

Insects

Location 1: Out in the Open (on Plants, in the Air, on the Ground)
See what you can find. Take a walk around your study site and look for obvious insects on plants, in the air, and on the ground. Draw or describe the different insects you see.

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<th>Draw or describe the insects.</th>
<th>How many did you see? What was their prevalence?</th>
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How many different types of insects did you find?__________________

Location 2: Under Rocks and Logs
Look a little closer. Find rocks and logs in your study site that you can look underneath. Draw or describe the different insects you see.

<table>
<thead>
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<th>Draw or describe the insects.</th>
<th>How many did you see? What was their prevalence?</th>
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How many different types of insects did you find in those places?__________________
Insects (continued)

Location 3: In Tall Grasses (Using a Net)
If you have tall grasses or meadowlike plants, use a butterfly net or a similar net to explore further. Sweep the net gently back and forth through the tall grasses. Check inside your net to see if you scooped up any insects hiding among the plants. Draw or describe the different insects you see.

<table>
<thead>
<tr>
<th>Draw or describe the insects.</th>
<th>How many did you see? What was their prevalence?</th>
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How many different types of insects did you collect in your net? ________________

Location 4: In Trees and Shrubs (After a Shaking onto a Sheet)
If you have small trees or shrubs, lay a white poster board or sheet on the ground around and under your tree or shrub. Gently, yet firmly, shake or thump on the main stem/trunk of the tree or shrub ten times. The idea is to shake insects out of the branches, but not damage the plant. Take a look at your white poster board and count the types of insects that you found. Draw or describe the different insects you see.

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<thead>
<tr>
<th>Draw or describe the insects.</th>
<th>How many did you see? What was their prevalence?</th>
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How many different types of insects did you find in your tree/shrub? ________________
18 U.S.C. 707
4-H Activities Report

This report will help you keep a better record of your club activities. Fill it in as you complete each activity or assignment. Refer to this record when you are entering county, state, and national programs. Ask your local leader to explain these programs to you.

My 4-H Activities Report for the 20____ Club Year

Projects taken

Offices held

Club

County

“Show-and-tells” given to

Family

Friends

Local club

County

Regional

State

News articles

Radio

TV

Things done to improve my health

Community service or citizenship work done

By myself

With club

Number of meetings my club(s) held this year ______. Number I attended ______.

Number of new members I encouraged to join 4-H ______

Number of boys and girls I helped with projects ______

In what way? ______

Check those attended and tell how you helped

☐ 3- or 4-day camp

☐ Roundup

☐ National 4-H Congress

☐ 1-day camp

☐ Teen Leader Retreat

☐ National 4-H Conference

☐ Club or county tours

☐ State 4-H Capital Days

☐ State Leadership Conference

☐ Club picnic

☐ Camp Leadership Training

☐ Judging training

☐ Countywide picnic

☐ Penn State 4-H Achievement Days

☐ Others: ______________

☐ County fair

☐ Pennsylvania Farm Show

☐ ______________________

☐ Achievement programs

☐ National 4-H Week

☐ ______________________
4-H CREED

I believe in 4-H Club work for the opportunity it will give me to become a useful citizen.

I believe in the training of my HEAD for the power it will give me to think, to plan, and to reason.

I believe in the training of my HEART for the nobleness it will give me to become kind, sympathetic and true.

I believe in the training of my HANDS for the ability it will give me to be helpful, skillful and useful.

I believe in the training of my HEALTH for the strength it will give me to enjoy life, to resist disease and to work efficiently.

I believe in my country, my state, and my community, and in my responsibilities for their development.

In these things I believe, and I am willing to dedicate my efforts to their fulfillment.

extension.psu.edu
Penn State College of Agricultural Sciences research and extension programs are funded in part by Pennsylvania counties, the Commonwealth of Pennsylvania, and the U.S. Department of Agriculture.

This publication is made possible through Pennsylvania 4-H educational materials fees.

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Produced by Ag Communications and Marketing
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Code 4H0077 5C11/16spectrum