INVASIVE SPECIES HANDBOOK

A Resource for Educators

Grades 3–8






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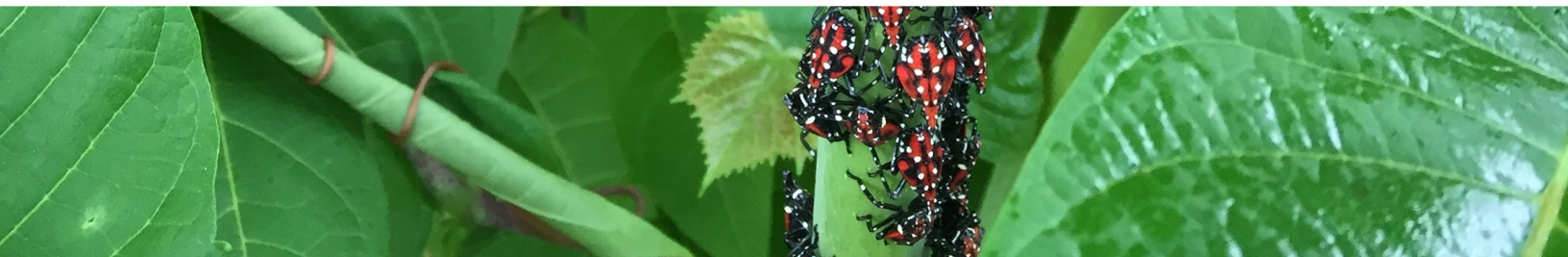

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2021

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TABLE OF CONTENTS

CHAPTER 1

What Is an Invasive Species?

Learning Objectives

- *Understand the difference between invasive species and non-native species.*
- *Name at least three traits of invasive species.*
- *Name at least two invasive species in the U.S.*

An invasive species is any living non-native organism, such as an animal or plant, that has arrived to a new area and causes harm to the environment, economy, or the health of other organisms, including humans. A native species occurs naturally in a particular area. The term "invasive" is usually reserved for the most harmful non-native species, but not all non-native species are harmful. For example, peach trees are native to Asia but were introduced to the rest of the world for the fruit to be eaten and enjoyed.

Invasive species usually have special traits, such as *fast growth, rapid reproduction*, *high dispersal ability*, and *behavioral flexibility*, that enable them to succeed in their new habitat. In addition, they are typically generalists that feed on a wide variety of food items or tolerate a wide range of environmental conditions. For example, the brown rat, also known as the Norway rat, is a generalist invasive species that feeds on a wide range of crops (Fig. 1). It has invaded countries all over the world and has resulted in the extinction or range reduction of native species through predation and competition for resources. Non-invasive species, on the other hand, tend to be specialists that feed on a limited number of food items or require specific environmental conditions to survive.

Fig. 1. The Norway rat is native to northern China and can now be found on every continent except Antartica.

Note, however, that there are some exceptions to the generalist and specialist rule. The emerald ash borer (EAB) is a tiny (½ inch long) invasive beetle that specializes on ash trees (Fig. 2). EAB is considered to be one of the most destructive forest insects to ever invade the U.S. It has killed millions of ash trees in the U.S. since its discovery in 2002. The EAB life cycle begins with eggs that adults lay on the bark of ash trees. After eggs hatch, the larvae (immature life stage) chew into the tree, creating snake-like trails that prevent the flow of water and nutrients, and eventually kill the tree. When EAB densities are high, small trees can die within one to two years, whereas large trees are killed within three to four years.

Fig. 2. Emerald ash borer is native to Asia and now occurs in more than 30 eastern and midwestern states. It has not been detected in Utah.

Did you know?

There are a lot of terms used interchangeably when referring to invasive species, such as "non-native," "non-indigenous," "alien," "exotic," "foreign," and "introduced" species, or even "hitchhikers" and "invaders." Some of these terms, however, may be viewed by some as derogatory, insensitive, and related to xenophobia against humans. Consequently, their appropriateness is currently under discussion by respective professionals. Further, many professional societies, such as the Entomological Society of America and the American Ornithological Society, are in the process of renaming species whose common name contains a racist or offensive slur; stereotypes a culture in a negative light; or honors a figure that held slaves, promoted racism, or participated in crimes against humanity.

Did you know?

Some non-native species have positive impacts, such as providing food for native species and helping to control invasive species. For example, the samurai wasp is an exotic **natural enemy** of the invasive brown marmorated stink bug (BMSB) that damages various crops in the U.S. (Fig. 3) The female wasp lays its eggs inside BMSB eggs; the wasp egg hatches and the larvae (immatures) feed on the developing stink bugs before chewing their way out. The wasp is considered the most promising agent for classical biological control of BMSB, and was imported from Asia to quarantine facilities in the U.S. for testing. In the meantime, adventive populations have been detected in the U.S., including in Utah.

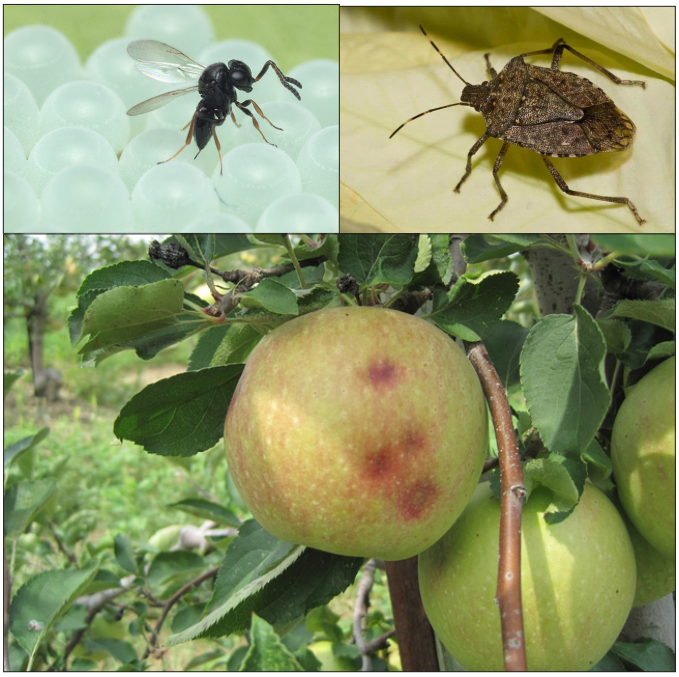

Fig. 3. The samurai wasp (top left) is a natural enemy of the brown marmorated stink bug (top right) in their native range of Asia. Both species can be found in parts of the U.S. The stink bug causes feeding damage to multiple crops, such as apple (bottom), peach, corn, and tomato.

Another trait of some invasive species is the lack of predators or diseases in the new environment. For example, Asian carp (bighead, black, grass, and silver carp) were imported to the U.S. in the 1970s for human food and to control algal blooms in aquaculture ponds and wastewater treatment plants (Fig. 4). Eventually, the carp escaped confinement and invaded the Mississippi River and other rivers and tributaries. In their native habitat, Asian carp are held in check by natural predators. In the U.S., there are no native species large enough to prey on adult carp. These invasive fish are now overtaking waterways and destroying natural food webs.

Fig. 4. The grass carp is one of four invasive Asian carps found in the U.S.

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Emerald Ash Borer Information Network (http://www.emeraldashborer.info/).

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Fig. 4. Eric Engbretson, US Fish and Wildlife Service, Bugwood.org

Vocabulary

Adaptation: the modification of a species over time so that it can be better suited to survive in its environment.

Adventive: a species that is new to an area but not yet fully established there.

Classical biological control: the importation and release of an agent (natural enemy organism) to control an exotic pest. Classical biological control agents are carefully considered before being released into the environment.

Generalist: the ability for an organism to live in various environmental conditions and survive off many different types of resources.

Invasive species: a non-native species that has been introduced to a new area and causes harm to the environment, economy, or the health of other organisms.

Native species: a species that originated in and normally lives in a certain area or habitat.

Natural enemy: an organism that kills or reduces the numbers of another organism. Natural enemies may include predators, parasites, parasitoids, or pathogens.

Non-native species: a species that has been introduced to a new area. Non-native species may also be called "alien," "exotic," or "introduced" species.

Parasite: an organism that lives on or in a host organism and gets its food from or at the expense of its host.

Parasitoid: an organism that lives in close association with its host at the host's expense, eventually resulting in the death of the host.

Pathogen: a bacterium, virus, or other microorganism that can cause disease.

Specialist: a living organism that requires specific resources to survive.

Activity 1: Create Competing Native and Invasive Species

Time: 30–45 minutes **Suggested grade group:** 6–8

Materials: white paper; markers, colored pencils, or crayons

Lesson: In this activity, students will choose or create a native species that can be found in a select ecosystem (e.g., forest, desert, grassland), and then draw it on a sheet of paper. Below their drawing, the students should write 1–2 paragraphs about this species (e.g., where it lives, what it eats).

On the back of the paper, the students should create and then draw an invasive species that would outcompete the native species. They should also write 1–2 paragraphs about the invasive species, including information about the following:

- How did this species arrive in the U.S.?
- What habitat does this species lives in?
- What adaptations (e.g., behavioral, morphological) allow this species to thrive in the new habitat?
- Why is this species "unwanted" (i.e., describe the negative impacts associated with this species)?

Afterwards, ask students to volunteer to describe the interaction between their two species to the entire class.

Activity 2: Demonstrate the Spread of the Invasive Emerald Ash Borer

Time: 30 minutes **Suggested grade group:** 3–5

Materials: white paper; markers, colored pencils, or crayons; scissors

Lesson: In this activity, students will first watch the video "The Nature Walk: Understanding the Life Cycle of the EAB."

After the video, divide the class into two groups, with one group containing about two-thirds of the class. The larger group will be tasked with drawing an ash tree on paper and then cutting it out. Group 2 will be tasked with drawing 3–5 emerald ash borers (EAB) on paper and then cutting them out.

Afterwards, the students will play a game of tag and are designated either as an ash tree or an EAB. The "EABs" have to tag the "ash trees." Every time an EAB tags an ash tree, they should give the ash tree one of their extra EABs to signal that the ash tree is now infested with EAB. When an ash tree is tagged, that student is now out of the game and has to sit on the sidelines. Play the game until all of the trees are "infested" with EAB and then ask the students what it means if all of the ash trees eventually disappear.

Activity 3: Manage an Invasive Species With a Natural Enemy

Time: 45 minutes **Suggested grade group:** 6–8

Materials: white paper; markers, colored pencils, or crayons

Lesson: In this activity, students will first watch the video "The Emerald Ash Borer Is Coming."

After the video, ask the class the following questions:

- Why is EAB considered an invasive species?
- What is the negative impact of EAB?
- What are the methods scientists use to treat the ash trees and to get rid of EAB?
- What are the three things you could do at home to help stop the spread of EAB?

Then divide the students into groups of about three to four. Each group will be tasked with creating their own "natural enemy" of EAB. Students will imagine an animal, plant, or other living organism capable of taking down this invasive insect. Have them name their natural enemy, list some of the characteristics that allow it to defeat EAB, and then draw a picture of this organism. Each group should then spend a few minutes presenting their creation to the entire class.

After the presentations, tell the students about *Cerceris fumipennis*, a solitary digger wasp found in eastern North America. The female wasp preys on metallic, wood-boring beetles, such as EAB. She uses her stinger to inject paralytic venom into the beetle and then will take the beetle to her underground nest. The wasp then lays an egg on the beetle and, once the egg hatches, the larvae will feed on the paralyzed beetle. Every female collects an average of two beetles per day, so this greatly reduces the population of beetles. Finally, play the video "Whack a Wasp" for the class so they can learn more about this wasp.

CHAPTER 2

Environmental Impacts

Learning Objectives

- *List two ways that invasive species can affect an ecosystem.*
- *List the characteristics of a healthy ecosystem.*
- *Understand how an invasive species can endanger native species.*

As mentioned in Chapter 1, invasive species harm the environment, economy, or the health of other organisms. In this chapter, we focus on how invasive species threaten the environment and specifically biodiversity, which is a measure of the variety of organisms, such as animals and plants, within an ecosystem. A healthy ecosystem has abundant habitats, a strong food web, and a network for nutrient movement. Invasive species affect ecosystems by reducing native plant communities, disrupting food chains, increasing soil erosion and wildfires, decreasing quality of habitat, and interfering with ecosystem services. The loss of any of these ecosystem components threaten the livelihoods of native species. Invasive species can decrease biodiversity by becoming the dominant species in a habitat and consequently reducing the number of species living in that environment.

For example, the Burmese python is a 20-foot long constricting snake that is native to Asia and was intentionally imported to the U.S. for the pet trade (Fig. 1). It wreaked havoc on the Everglades National Park ecosystem after a python breeding facility was destroyed by a hurricane in 1992 and the snakes escaped.

Fig. 1. The Burmese python is native to Asia, but after a series of accidental releases and escapes, it has now overtaken Everglades National Park.

Did you know?

Timber production is an important ecosystem service provided by forests. Timber refers to wood at any stage after the tree has been felled and is used for building materials, fuel to generate power, and paper production. Timber production is threatened by several natural and human-assisted impacts, including invasive species such as sudden oak death, Dutch elm disease, and emerald ash borer.

Burmese pythons have a rapid growth rate and can produce large quantities of eggs; therefore, they quickly became the dominant predator. The snakes likely then contributed to the decline of several mammals, such as opossums, raccoons, rabbits, and foxes, as well as some wading birds.

Invasive species may also play a role in other species becoming threatened (in danger of extinction) or endangered (in immediate danger of extinction). For example, cheatgrass is an invasive plant that has recently dominated parts of the Intermountain West due to its ability to survive in disturbed areas. Since cheatgrass is highly flammable and usually found in high densities, it can provide large amounts of fuel to create very intense and severe fires. Unfortunately, the greater sage-grouse, which relies on sagebrush shrubs for food and shelter, is now near-threatened, in part due to cheatgrass and the ensuing loss of suitable habitat (Fig. 2).

Fig. 2. The greater sage-grouse (top left) has become near-threatened after cheatgrass (top right) invaded the native sagebrush habitat which is vital nesting habitat for sage-grouse.

Vocabulary

Biodiversity: variability of life on earth or in a particular habitat.

Ecosystem: a community of living organisms interacting with the non-living physical environment.

Ecosystem service: the processes or resources of an ecosystem that directly or indirectly benefit humans or enhance social welfare (e.g., pollination, pest and disease management, nutrient recycling, soil fertility, fresh water, erosion protection, timber production).

Endangered: a species that is very likely to become extinct in the near future.

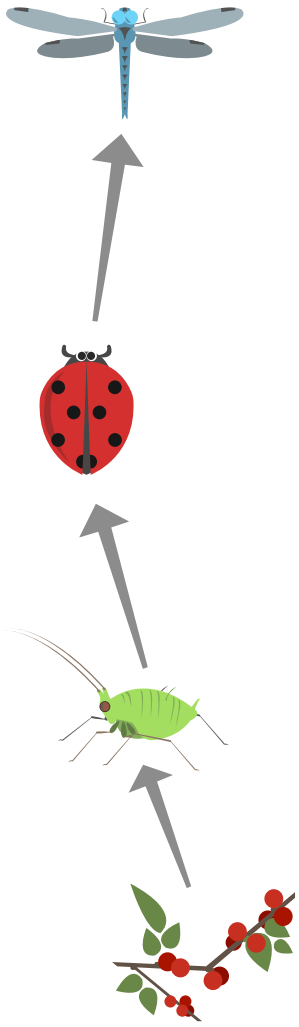
Extinction: when all members of a particular group (species) die.

Food web: when multiple food chains are linked together to form a network.

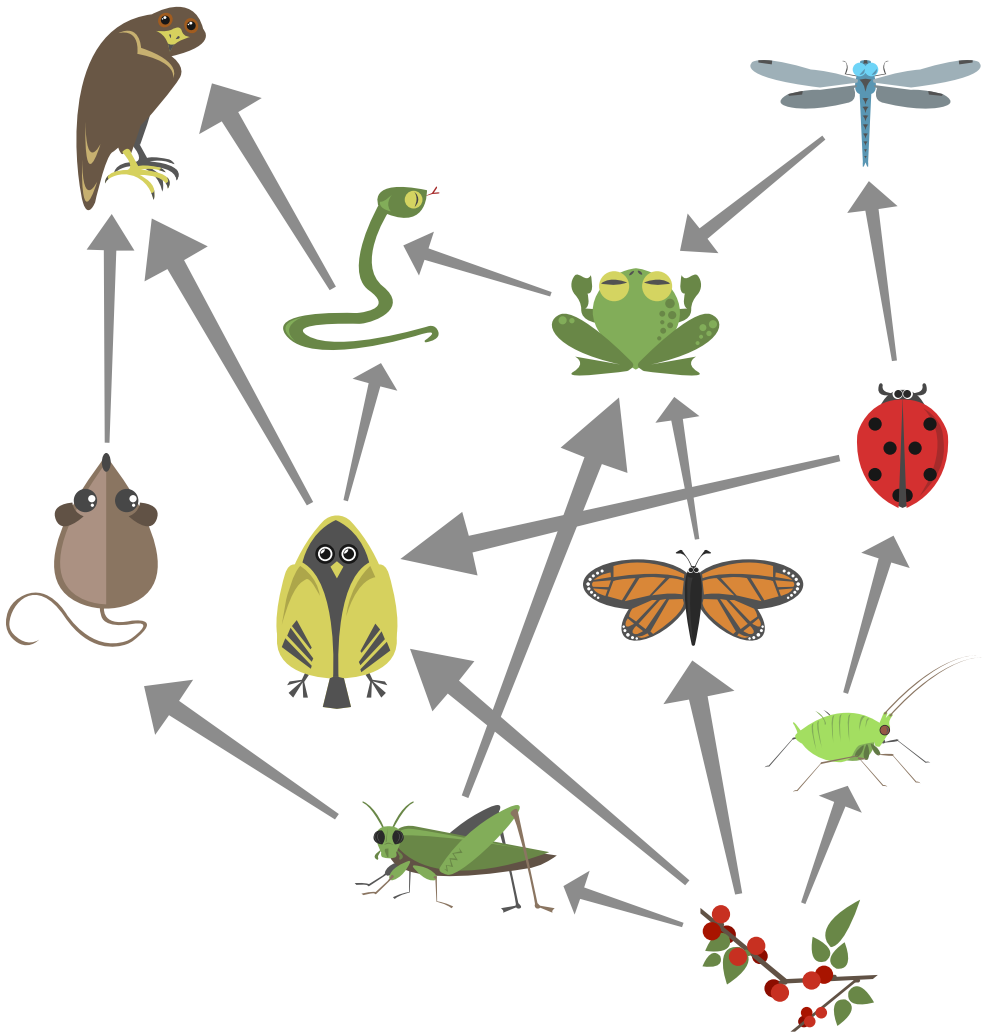
Food chain: a model that shows the linear sequence among species in an ecosystem — essentially who eats what.

Threatened: a species that is likely to become endangered in the future.

Food Chain



Food Web



Activity 1: The Importance of Biodiversity

Time: 45–60 minutes **Suggested grade group:** 6–8

Materials: colored construction paper; colored pencils and/or crayons; scissors; tape; copies of the Invasive Species Cards (see Appendix A on pages 28–35)

Lesson: Each student will be assigned to one of the following ecosystems: desert, forest, rainforest, freshwater, tundra, marine, or prairie. Students should come up with 3–6 species that are native to that particular ecosystem (e.g., a polar bear is native to the tundra). They should then draw this landscape and each of the associated native species. Afterwards, the students should review the Invasive Species Cards (with an image of the species on the front of the card and a description on the back) that correspond to their assigned ecosystem. Students should choose which invasive species invaded their ecosystem and then re-draw the ecosystem after the arrival of the invasive species. After students finish their "after" drawing, ask for volunteers to present their before and after images and then discuss how the invasive species impacted that ecosystem.

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Fig. 1. Skip Snow, National Parks Service, Bugwood.org

Fig. 2. (Top left) Terry Spivey, USDA Forest Service, Bugwood.org; (Top right) Steve Dewey, Utah State University, Bugwood.org; (Bottom) John M. Randall, The Nature Conservancy, Bugwood.org

CHAPTER 3

Economic Impacts

Learning Objectives

- *Learn how invasive species can impact the economic industry.*
- *Understand how federal laws and company policies can restrict the spread of invasive species.*

Besides causing environmental harm, invasive species can cost the U.S. and other countries billions of dollars to manage and can have devastating consequences on tourism and outdoor recreation, property values, agricultural productivity, public utility operations, and human health. Impacts to human health are discussed in more detail in Chapter 4.

For example, Eurasian watermilfoil has invaded almost every state in the continental U.S. except for Wyoming. Native to North Africa, Europe, and Asia, this invasive weed has negative effects on aquatic ecosystems and fisheries (Fig. 1). It has also been shown to have extensive impacts on recreational activities like boating, swimming, water skiing, and angling, and consequently reduces real estate values in tourist areas. It is now considered the greatest threat to Michigan's $17.7 billion tourism economy that supports over 200,000 jobs.

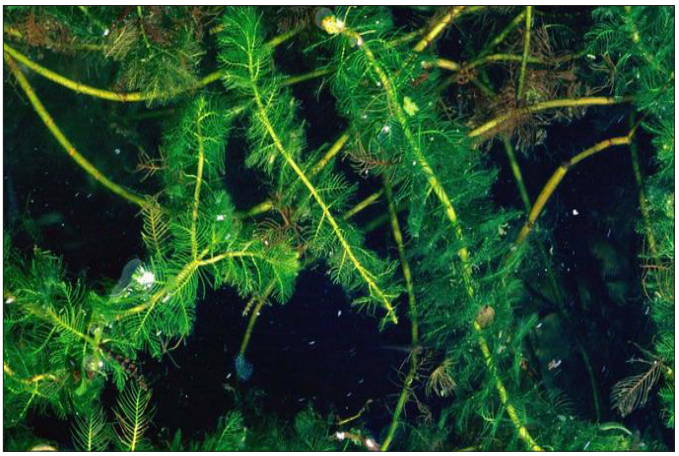

Fig. 1. The Eurasian watermilfoil forms dense surface canopies that create unsuitable habitat for native species and hinders recreational activities.

Further, invasive species can harm agricultural industries by contaminating produce and tarnishing crops. For example, spotted wing drosophila is a small fly native to Southeast Asia and found in almost every U.S. state, damaging berries, stone fruits (cherries, peaches), and soft-skinned vegetables (tomatoes). The female fly lays eggs inside the fruit and then the developing larvae (immature life stage) will feed on the fruit's flesh, causing extensive damage (Fig. 2). The damaged fruit cannot be sold for human consumption and results in income loss for farmers. In some parts of the country where this pest is a major concern, millions of dollars are spent each year trying to control this pest, yet some areas still report high crop yield loss.

Fig. 2. Spotted wing drosophila infests soft fruits, such as cherry, raspberry, and strawberry. Primary damage to fruit is caused by puncture wounds from egg-laying and larval tunneling and feeding on the fruit's flesh.

Finally, Japanese knotweed (Fig. 3) is a weed native to Asia that infests riparian areas, clogs waterways, increases flood risk, and shades out native species. More so, its roots can extend 40 feet and penetrate the ground up to 10 feet and therefore break through pavement and concrete, posing risk to walls, foundations, and septic systems.

Fig. 3. Not only economically damaging, Japanese knotweed can spread rapidly and establish monoculture stands that reduce native plant communities. This species thrives in disturbed areas and can tolerate a wide range of environmental conditions.

Vocabulary

Agricultural productivity: the measured ratio of agricultural outputs to agricultural inputs.

Economy: the resources and wealth of a country or region, specifically in terms of producing and consuming services and goods.

Larva (pl. larvae): the wingless, worm-like, immature form of an insect that undergoes *complete metamorphosis*, whereby the insect's life cycle undergoes four stages, including egg, larva, pupa and adult. *Incomplete metamorphosis* describes insects that undergo three stages: egg, nymph, and adult, with the nymphs looking similar to the adults, just without fully developed wings).

Public utility: a public service organization that is subject to government regulation (i.e., sewage works, electricity supplies, or public transportation).

Activity 1: Orchard Grower Case Study

Time: 30–45 minutes **Suggested grade group:** 3–5

Materials: one die and 20 tokens for each student (tokens may include poker chips, stickers, coins, beads, pennies, etc.); copies of the Orchard Grower Case Study Worksheet (2 pages) for each student (see Appendix B on pages 36–37)

Lesson: In this activity, students will become an apple farmer to understand how invasive species can impact their crops and pocketbook. Have each student come up with a name for their orchard and then give each of them a die and 20 tokens that symbolize the apple trees in their orchard. Describe to the new farmers that the fruit of each apple tree is worth $100, so their small orchard is worth $2,000. Explain that the codling moth (Fig. 4) has just invaded their orchard. Have the farmers roll the die to symbolize the first generation (i.e., the first set of offspring produced) of codling moth infestation. The number they get from the die is the number of trees they lose apples from, and thus, the number of tokens they will set aside from their pile. The farmers should repeat this twice to represent three generations in a season. They should keep track of the number of apple trees that were lost each generation as well as the total value of the orchard by filling out the record sheet in Appendix B. At the end of three generations, the farmers will calculate the cumulative impact to their orchard by determining the remaining number of trees and the final worth of their orchard. Students should then answer the questions found at the end of the record sheet.

Fig. 4. The codling moth is thought to have first arrived to the U.S. in the mid 1700s. It is now found in all parts of the U.S. Apple injury is due to the larval feeding on the seeds and surrounding fruit flesh, causing unmarketable fruit and huge monetary losses to growers.

Activity 2: Ecosystem Services

Time: 30-45 minutes **Suggested grade group:** 6–8

Materials: Copies of the Ecosystem Services Worksheet for each student (see Appendix C on page 38); Alaska Industry Papers (see Appendix D on pages 39–42); colored pencils or crayons

Lesson: In this activity, students will learn the importance of ecosystem services that support the Alaskan economy and how invasive species threaten specific industries.

Provide each student with a copy of the Ecosystem Services Worksheet. Next, play the Conservation International "People Need Biodiversity" video. After the video, ask for volunteers to define biodiversity and ecosystem services. After students understand that ecosystem services are provided by biodiversity, ask them to provide examples of ecosystem services seen in the video. List their ideas on the writing display in your classroom.

Let the students know that four major natural resource industries in Alaska include tourism, fisheries, timber, and agriculture. This activity has four information papers with photos and details on each industry type. Split the class into equal groups of four or five students, based upon the size of the class. Randomly assign each group one of the four industry papers. Each group should then read about their assigned industry and answer the corresponding questions. At the bottom of their industry paper will be a picture and description of an invasive species. The students will then identify ways this invasive species threatens their assigned industry.

After completing their worksheets, have one representative from each group discuss their assigned industry and the invasive species that threatens it.

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Fig. 1. Barry Rice, sarracenia.com, Bugwood.org

Fig. 2. Peter Shearer, Oregon State University

Fig. 3. Philip Rusted, Thurlow Countryside Management (r&d), Bugwood.org

Fig. 4. (Left) Csaba Szaboky, Bugwood.org, (Right) Clemson University — USDA Cooperative Extension Slide Series, Bugwood.org

CHAPTER 4

Health Impacts

Learning Objectives

- *Understand how invasive species can directly and indirectly impact human, animal, and plant health.*
- *Understand how invasive species can contribute to bioaccummulation of toxins through a food chain.*
- *Learn how invasive mosquitoes vector human diseases and ways humans can prevent infections.*

Along with harming the environment and economy, as discussed in previous chapters, invasive species can also negatively affect the health of humans, other animals, and plants. Invasive species can transmit and vector infectious diseases to new regions, as well as expose humans to physical injury, allergens, toxicants, and biotoxins.

The Asian tiger mosquito is just one example of how an invasive species can directly impact human health. This insect was accidentally introduced to the U.S. in the 1980s via eggs on imported tires from Asia, and can now be found in more than 40 states. It is active during the day and exhibits aggressive biting behavior, making it a more common vector of diseases such as West Nile virus, dengue fever, and La Crosse encephalitis. The West Nile virus has caused the death of over 2,000 Americans with more than 50,000 cases since 1999. Although 80% of humans are asymptomatic, common symptoms include vomiting, fever, headache, body aches, and a rash. Severe cases may include convulsions, vision loss, paralysis, numbness, or coma. There is currently no vaccine for West Nile virus, but doctors can administer treatments to those infected. This virus can also impact birds, dogs, horses, chipmunks, squirrels, bats, and other animals. To stop the spread, insecticides are sprayed in areas where mosquitoes are likely to come into contact with humans.

Did you know?

Invasive species can introduce toxins and chemicals into a food chain. For example, as invasive zebra mussels filter water as they feed, they may also ingest PCBs (Polychlorinated Biphenyls) which are harmful man-made chemicals that have been used in industrial and commercial applications but are now banned for health reasons. Yet PCBs can still be found in some waterways. These contaminants get incorporated into the shell and tissues of the zebra mussels as they feed and then get transferred to other animals further along the food chain, including humans. PCBs can also be passed to infants from their mothers. If exposed to high levels of PCBs, humans have an increased risk of developing cancers, skin problems, and other complications.

Zoonotic diseases have become increasingly common throughout the world, with three out of four new human infectious diseases coming from animals. For example, the majority of tick-borne diseases are zoonotic. Some ticks are invasive species, such as the Asian longhorned tick, which is a suspect vector for Rocky Mountain Spotted Fever, one of the deadliest bacterial diseases in the U.S. This disease causes headache, fever, and rash and can lead to permanent damage, such as the amputation of limbs from damage to blood vessels in these areas, hearing loss, mental disability, or paralysis. The disease can be deadly if not addressed early with the correct antibiotic treatment.

Invasive species can cause physical harm to humans and other animals. An example of this can be seen with the red imported fire ant, which is native to South America but is now found throughout some regions of the southeastern and western U.S. These ants can sting and inject a venom that can lead to chest pains, paralysis, seizures, anaphylaxis, or even death to domestic animals, livestock, wildlife and, in rare cases, humans. Stings can also lead to increased medical costs to affected humans.

Invasive species also indirectly impact human health. For example, the water hyacinth is native to southeast Asia and was introduced to North America in 1884 via the ornamental plant

trade. This species causes oxygen depletion, fish kills, and algal blooms in freshwater ecosystems. Further, the water hyacinth provides suitable habitat for mosquitoes that vector the *Plasmodium* parasite that causes malaria, as well as snails that vector the waterborne parasite *Schistosoma mansoni*. Both of these diseases can cause fever, chills, or even death if left untreated.

Invasive species also have the ability to impact human health by limiting food and water availability. For example, the invasive maize leafhopper is native to South Africa and is decimating the maize crops in sub-Saharan Africa, the Middle East, India, and West Asia. When this insect feeds, it injects the plant with maize streak monogeminivirus (MSV) which causes plant death or stunted growth. Maize leafhopper threatens the food security of millions of people and livestock in Africa that rely on this crop.

Vocabulary

Biotoxin: toxic substances that have a biological origin.

Toxicant: any toxic substance that is man-made or naturally occurring.

Vector: an organism, such as a biting insect or tick, that transmits diseases or parasites between plants or animals.

Zoonotic disease: an infectious disease caused by a pathogen that has moved from an animal to a human.

Infectious disease: any disease caused by a pathogen such as a bacteria, virus, fungus, or parasite. Infectious diseases can impact various animals, not just humans.

Activity 1: Mosquito Madness

Time: 20–25 minutes

Suggested grade group: 3–5

Materials: Mosquito Madness Board Game (one per group, see Appendix E on page 43); dice; a small unique object for each student (e.g., a token, bobby pin, eraser, coin, small figurine)

Lesson: In this activity, students will play a board game to learn how West Nile virus is spread by the Asian tiger mosquito and ways they can prevent infection. Start the activity by reemphasizing the information presented earlier in this chapter about the mosquito and virus. You may also want to play the "Mosquito Season: How to Identify Symptoms of West Nile Virus" or "Asian Tiger Mosquitoes" videos before proceeding.

Split the class into groups of 3–5 and hand each group a printed copy of the Mosquito Madness board game. Each student within a group should be given a small unique object to use as their gamepiece. Students begin the game by placing their gamepiece on the home base square. The goal of the game is to be the first player to return to home base.

The youngest player will start the game by rolling the dice and then advancing the correct number of spaces clockwise around the board. The player to the left of the youngest player goes next and continues clockwise. The players should follow the instructions on the board spaces they land on. If the students land on a blank space, they do not have to do anything for that round and are safe. After the first player has returned to home base, the game is over.

Depending on time, you can have each group play multiple games. At the end of the activity, have the students return the board games and their game pieces. Then, have the students come up with ways to prevent bites that are not listed on the game.

Activity 2: Chain of Toxins

Adapted from NYSDEC Region 1 Freshwater Fisheries I FISH NY Program, Food Web & Bioaccumulation Lesson Plan

Time: 30–45 minutes **Suggested grade group:** 6–8

Materials: Chain of Toxin Cards (see Appendix F on pages 44–46); tape or chalk; small buckets or cups; two different colored poker chips (or similar items, 30 of each color)

Lesson: Students will track how toxins can be introduced to humans through the food chain. Show the class the videos "Impacts of Zebra Mussels" and "Silent Invaders Zebra Mussels 2013." Afterwards, reinforce the lessons from the videos by asking the following questions: What problems do zebra mussels cause? What species are negatively impacted by zebra mussels? Then remind the students what a food chain is (see Chapter 2) by drawing the following food chain on the white board:

1. Phytoplankton: extremely small algae that photosynthesize (use sunlight to produce sugars and other nutrients). Phytoplankton start the food chain.
2. Zooplankton: microscopic animals that feed on phytoplankton.
3. Zebra mussels: consume zooplankton as they filter water and strain out edible material.
4. Round gobies: invasive fish that consume and help control zebra mussel populations.
5. Walleyes: predators of round gobies.
6. Humans: consume walleyes and are at the top of this food chain.

Next, assign each student a species within the food chain, with the exception of phytoplankton, and then split the class into groups, with a ratio of about 5 (zooplankton) to 4 (zebra mussel) to 3 (round goby) to 2 (walleye) and only 1 human. Each student should be given a Chain of Toxins Card (see Appendix F), and follow the instructions on their assigned card.

Place 5 strips of tape on the floor or draw 5 lines on the ground with chalk. These lines represent the food chain. Space the lines about 4 to 5 feet apart, with the line lengths decreasing up the chain, like a pyramid. The zooplanktons will stand on the bottom line, the zebra mussels on the second line, and so on. Scatter about 30 yellow poker chips on the ground near the zooplankton. These yellow chips represent the phytoplankton. Next, randomly scatter 20 red poker chips near the zebra mussels. These chips represent the PCB toxin, but don't tell the students until the end of the game.

Hand each zooplankton and zebra mussel a bucket. Each species will now be given an opportunity to "feed" on their assigned prey, but only one level of the food chain will feed at a time. In the first round, zooplankton will have 10 seconds to feed on the phytoplankton (yellow poker chips). In the second round, zebra mussels can either feed on zooplankton by taking their prey's food bucket or feed on the red poker chips. To take a prey's food bucket, the zebra mussels must first tag their prey on the arm or shoulder. Continue this progression until each level of the food chain has been allotted 10 seconds to feed. At the end of the game, each student with a bucket should count the number of poker chips they have of each color and then return the chips and buckets. On the white board, record the number of chips per color that each species collected next to the drawing of the food chain.

Tell the students that the red poker chips are PCBs (Polychlorinated Biphenyls). Remind the class that these chips entered the food chain through the zebra mussels. Remind students that the flow of toxins up a food chain has the potential to negatively impact human health and it all starts with the invasive species (zebra mussel) introducing the toxin in the food chain.

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Image Credits

Fig. 1. (Left) Susan Ellis, Bugwood.org; (Right) Roland Balik from Dover Air Force Base, DE, via Wikimedia Commons

Fig. 2. Public Health Image Library (PHIL), Centers for disease control and prevention (CDC), via Wikimedia Commons

Fig. 3. USDA APHIS PPQ - Imported Fire Ant Station , USDA APHIS PPQ, Bugwood.org

Fig. 4. (Left) Charles Olsen, USDA APHIS PPQ, USDA APHIS PPQ, Bugwood.org; (Right) CIMMYT, flickr.com

CHAPTER 5

Pathways of Spread

Learning Objectives

- *Learn the multiple pathways by which invasive species can spread to new areas.*
- *Understand that humans can intentionally and unintentionally spread invasive species.*

Invasive species can arrive to new areas through a variety of pathways. Although some of these pathways include natural migration (e.g., assisted dispersal by wind and water currents), far too many invasive species are introduced by humans either intentionally or unintentionally. Intentional pathways include the multibillion-dollar exotic pet trade industry or mail order shopping through the internet. The goldfish is an example of an invasive species that was intentionally introduced to the U.S. after local pet owners began dumping the unwanted fish into ponds and rivers (Fig. 1). The goldfish originates from Asia, but can now be found in natural freshwater areas in all states due in part to its ability to rapidly reproduce in large numbers.

Fig. 1. Goldfish can cause a variety of problems for native fish species. For example, it uproots vegetation and stirs up sediment as it swims along the bottom of rivers and lakes. They can also release nutrients that cause harmful algal blooms, outcompete native fish for resources and space, and carry harmful bacteria and parasites.

Unintentional pathways include the movement of plant products (e.g., wood, fruits, seeds); recreational vehicles (boats) and other transportation networks (planes, trains, automobiles, container ships); agricultural and construction machinery; passenger baggage; and outdoor gear. For example, the invasive Japanese beetle (Fig. 2) made its way to the U.S. by hitchhiking in the soil of imported plants. It attacks over 300 plants, including ornamentals (e.g., rose, peony, hibiscus, hollyhock, maple, turfgrass), vegetables (e.g., asparagus, corn, rhubarb), and fruits (e.g., grape, apple, peach, cherry). The emerald ash borer (Fig. 3) is another invasive species that can spread to new areas unintentionally. This beetle, native to parts of Asia, can spread on infested wood, including firewood. It is now found in more than 30 midwestern and eastern states, killing tens of millions of ash trees.

Fig. 2. Adult Japanese beetles chew on leaves, flowers, and fruit. The larvae (immature life stage) attack plants below ground and feed mostly on the roots of grasses.

Fig. 3. Although emerald ash borer adults feed on ash leaves, the larvae are the damaging life stage. Larvae chew through the phloem and sapwood, creating serpentine-shaped galleries that disrupt the flow of nutrients and water, starving the tree.

Did you know?

Native species are adapted to survive in specific climates; however, when climate patterns change, such as an increase in normal rainfall and temperatures, native species may suffer if they cannot adapt to the new conditions. Since many invasive species can tolerate a wide range of environmental conditions, however, they are more likely to survive climate adjustments. Climate change has enabled invasive species to expand their ranges rapidly to northern latitudes. For example, kudzu is an invasive vine that is native to Japan and southeast China and does well in areas with mild winters and hot summers. It invaded the southeastern part of the U.S., where the climate is similar to its native range, but it has also been reported in North Dakota and Michigan, both of which often have snowy, below-freezing winters. These occurrences are likely to be driven, at least in part, by changes in climate.

Fig. 4. Kudzu grows rapidly, earning it the nickname "mile-a-minute" vine.

Vocabulary

Climate change: a change in normal climate patterns, such as temperature, over time.

Exotic pet: a non-native and unusual or rare animal (e.g., a chameleon or snake).

Intentional pathway: the deliberate movement of an organism outside its native range.

Pathway: means by which an invasive species moves from one location to another.

Unintentional pathway: the accidental movement of an organism outside its native range due to human activity.

Activity 1: Map the Spread #1

Adapted from National Geographic, "Introduction to Invasive Species"

Time: 30–35 minutes

Suggested grade group: 3–5

Materials: colored pencils, pens, or crayons; Map the Spread Worksheet (see Appendix G on page 47); access to a computer and internet

Lesson: Students will map the distribution and spread of an invasive species. Assign each student one of the following pests:

- Spotted lanternfly
- Emerald ash borer
- Brown marmorated stink bug

Give the students about 15–20 minutes to research their assigned species. You may want to direct students to the websites listed in the References and Additional Resources section in Chapter 5 (page 23). Tell the students they should identify at least the following information about their species:

- What is this species' native range?
- How does it spread to new areas?
- What impact does it have on native species?

After the students have researched their assigned invasive species, provide them with the Map the Spread Worksheet. The students should color in the state where the species first invaded the U.S. and then draw arrows to all other states that this species has invaded. Afterwards, the students should answer the questions that are listed below the map. Once the students have completed this activity, ask for volunteers to describe each invasive species to the rest of the class and encourage students to share findings that are different from their peers.

Activity 2: Map the Spread #2

Time: 30–60 minutes **Suggested grade group:** 6–8

Materials: access to a computer and internet

Lesson: In Part A of this activity, students will map the distribution of an invasive species. In Part B (optional), students will create a PowerPoint presentation about their assigned invasive species.

PART A: First, assign the students one of the following invasive species: nutria, monk parakeet, New Zealand mud snail, alligatorweed, elm seed bug, or medusahead. The students should then spend about 15–20 minutes researching their assigned species. You may want to direct students to the websites listed in Chapter 5's References and Additional Resources section (page 23).

After researching their assigned species, the students will then create a map using the National Geographic MapMaker Interactive. Before the students begin, walk them through the site, but become familiar with this tool yourself before introducing it to the students. Hover over the features on the left side of the screen to see a brief description of the functions of that feature. After giving a short demonstration/introduction, the students should then complete the following tasks:

1. Create two text boxes. One box should contain the name of the assigned invasive species; the other box should contain the student's name. It is best to use a large and dark font for these text boxes. Font size and color can be manipulated using the "Edit layers" feature.
2. Place a marker in the center of the state that was first invaded by the invasive species. To see state boundaries, the students must zoom in on the U.S. map.
3. Place a circle or rectangle on each additional state this species has invaded since its introduction.
4. Create two more text boxes, one that lists the ways this species spreads to new areas and another that names the species' native country or region.
5. Draw a line from the area this species is native to to the first invaded U.S. state. The map will then automatically calculate the total distance of the line. Click the last point to finish the line. The distance between the two points should then appear on the map.
6. Add a Climate Zone layer to the map. Layers are just additional information that can be displayed on the map. To add a layer, click on the Layers tab on the right side of the screen. Find the Climate Zones layer and then click the green plus sign button to add the layer to your map.
7. Click on the Legend tab to see which climate type coordinates with each color. Add another text box that lists the climate types where we find this invasive species.

After the students finish this part of the activity, remind them that many invasive species are generalists and can therefore tolerate a wide range of environmental conditions, sometimes even including climate conditions that are not found in their native ecosystem.

To complete this part of the activity, the students should save their map as a PDF by clicking on Print on the top bar of the map and then saving the map as a PDF. The students can turn in their map either by emailing it to you or printing it off and handing it in.

PART B: Each student will create a PowerPoint presentation that provides background information on their species, as well as its distribution and the reason behind its spread. The PowerPoint should contain each of the following items, preferably on its own slide.

- The name and a picture of their assigned invasive species.
- The distribution map created in Part A.
- Ways the invasive species has spread throughout the country.
- Describe any impacts the invasive species has on its non-native range.
- Current methods (if any) that are being used to control this species.

After each student has created their PowerPoint, ask for volunteers to present their PowerPoint. After the presentations, ask the class the following questions:

- Has anyone ever seen one of the invasive species that was presented today, and if so, when and where?
- Did you notice any similarities among the invasive species? Why do you think that is? Are there certain actions humans can do to stop that method(s) of transport across the U.S.?

Activity 3: Pathway Posters

Time: 60 minutes **Suggested grade group:** 3–5

Materials: access to a computer and internet; construction paper; markers, crayons, or colored pencils

Lesson: In this activity, students will create a poster to help prevent invasive species from spreading to new areas. Assign each student one of the following pathways of invasive species introduction and spread: internet sales; exotic pet trade industry; plant products (e.g., wood, fruits, seeds); recreational vehicles (boats); other transportation networks (e.g., planes, trains, automobiles, container ships); agricultural and construction machinery; passenger baggage; and outdoor gear. The students should then spend some time learning more about their assigned pathway by reviewing the USDA APHIS How They Spread site (or similar site). After about 15–20 minutes, the students should then create an informative and visually pleasing poster that highlights the following:

- The type of pathway.
- The type of species that can be spread through this pathway.
- What's at risk.
- What the public can do to help stop the spread.

The students can create their poster using paper and markers/crayons or sites like Canva, BeFunky, or PosterMyWall. After the students are done, ask for volunteers to present their poster. Afterwards, ask the class which activities they would be willing to do to prevent invasive species from spreading.

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Spotted Lanternfly

- USDA APHIS Spotted Lanternfly
- New York State Integrated Pest Management - Spotted Lanternfly

Emerald Ash Borer

- Emerald Ash Borer Information Network
- USDA APHIS Emerald Ash Borer

Brown Marmorated Stink Bug

- EddMaps Brown Marmorated Stink Bug Distribution Map
- USDA Brown Marmorated Stink Bug
- StopBMSB - Where is BMSB?

Image Credits

Fig. 1. US Geological Survey, Bugwood.org

Fig. 2. Whitney Cranshaw, Colorado State University, Bugwood.org

Fig. 3. (Main); Kelly Oten, North Carolina State University, Bugwood.org; (Inset) David Cappaert, Bugwood.org

Fig. 4. Jil Swearingen, USDI National Park Service, Bugwood.org

CHAPTER 6

Prevention, Monitoring, and Control

Learning Objectives

- *Learn what you can do to prevent invasive species from spreading to new areas.*
- *Learn what federal and state agencies are doing to prevent and control invasive species.*

Invasive species can be difficult to manage once they become established in a new area. Therefore, the best way to stop invasive species is to prevent them from arriving to new areas in the first place. As discussed in Chapter 5, many invasive species are unintentionally spread by human-assisted means, such as air and vehicle travel and recreational activities like camping, fishing, boating, and hiking. Therefore, it is important that the public come to understand how they can help prevent invasive species from establishing in new areas. Below are some simple activities that you can do to help keep these harmful species at bay.

- *Buy local.* Avoid transporting and shipping plant material or animals outside their area of origin. Buy local produce and firewood to avoid spreading invasive pests.
- *Keep it clean.* Remove plants, soil, and animals from your personal belongings and pets when you travel.
- *Learn to identify and look for signs.* Learn what new invasive species are in or around your region and then be sure to watch for signs of their presence. It only takes a few minutes to check plants, containers, and personal belongings for invasive hitchhikers!

- *Report suspicious species.* Contact your local county extension office or the state's department of agriculture if you suspect a new infestation of an invasive species.
- *Spread the word.* Tell your family and friends about invasive species and the environmental, economic, and health impacts that are associated with these species.
- *Learn to manage.* Learn management efforts for invasive species already present in your region.
- *Cooperate with agencies responsible for managing invasive species.* Federal and state agencies will oftentimes set up quarantines to restrict movement of regulated articles. Keep in mind that combating invasive species is a team effort!

Unfortunately, prevention is not always possible, so it is important that invasive species are detected soon after their arrival; otherwise, damage and control costs increase as an invasive species spreads over time (Fig. 1).

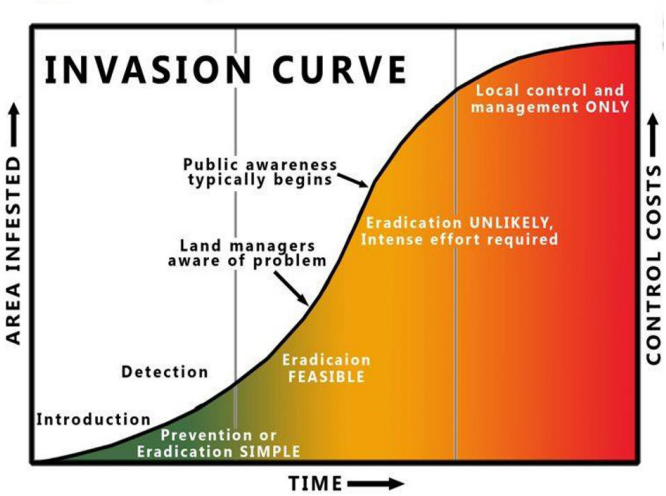

Fig. 1. The invasion curve shows that the more time an invasive species goes untreated, the area of infestation increases and the higher the cost of control.

Numerous federal and state agencies and programs conduct activities that support the early detection of invasive species. For example, the Cooperative Agricultural Pest Survey (CAPS) program is a national and combined effort between federal and state agencies to survey and monitor exotic pests of agricultural and natural plant resources. The Utah CAPS

program is cooperatively administered by the U.S. Department of Agriculture (USDA) through its Animal and Plant Health Inspection Service (APHIS), as well as Utah State University and the Utah Department of Agriculture and Food. However, other federal and state partners, such as the U.S. Forest Service, the U.S. Customs and Border Protection, and the Utah Division of Forestry, Fire and State Lands, are heavily involved with this program.

One example of an invasive species that is monitored by the CAPS program is the Old World bollworm (OWB). The larvae (immature life stage) of this invasive moth feed on more than 120 plant species, including corn, tomato, squash, bean, pepper, cotton, potato, and fruit (Fig. 2). OWB is considered the world's single worst insect pest of agriculture not only because it feeds on so many plant species, but also because of its ability to tolerate a wide range of environmental conditions. Learn more about the Utah CAPS program (Fig. 3) and other target pest species by visiting the Utah CAPS website (https://extension.usu.edu/pests/caps/).

Fig. 2. The Old World bollworm is native to areas of Europe, Asia, Africa, and Australia, and is regularly intercepted at U.S. borders.

Fig. 3. The Utah CAPS program places thousands of insect traps across the state each year to detect new invasive pests early in the invasion process. The plastic bucket trap is used to detect several moth pests.

Did you know?

Control measures may be necessary if an invasive species cannot be prevented or eradicated. Integrated pest management (IPM) uses multiple tools to solve pest problems, including biological, cultural, mechanical, and chemical control. Biological control involves the use of one species (natural enemy) to control another (pest). Cultural control uses crop rotation, sanitation, and other techniques to reduce pest pressure. Mechanical control uses physical methods, such as insect traps or barriers or screens, to remove or exclude pests. Finally, chemical control uses **pesticides** to kill pests. The use of biological, cultural, and mechanical control methods are preferred over chemical measures.

Vocabulary

Crop rotation: changing the type of crop grown in a single area after each season or harvest as a means to prevent loss of soil health.

Eradication: the removal or destruction of an organism.

Pesticides: a substance used for destroying a harmful pest, such as an insect or disease.

Regulated articles: any object that can carry an invasive species, such as a plant or plant product (firewood, fruit) or even equipment, trailers, or storage containers.

Sanitation: removing infested plant material, weeds, and other debris from an area.

Quarantines: the restriction of pest movement into areas where they do not occur.

Activity 1: Stop the Spread

Time: 20–25 minutes **Suggested grade group:** 3–5

Materials: writing display, such as a white board or chalkboard

Lesson: In this activity, students will learn how their personal actions can help stop or slow the spread of invasive species. First, remind the students that humans are the biggest spreaders of invasive species, but there are things we can do to help prevent the spread of invasive species. Afterwards, play the USDA video "Seven Ways to Leave Hungry Pests Behind" and then break students into groups of 3–5, depending on the size of the class. Each group should come up with a list of five ways to help prevent the spread of invasive species that were not already covered in the video. To help the students come up with ideas, remind them that the spread of invasive species can occur in nearly any setting or during a lot of different activities. After about 5–10 minutes, ask a representative from each group to write their list on the writing display in your classroom. Afterwards, discuss the list with the entire class and, if needed, ask the student representatives to explain the clarification behind their ideas.

Activity 2: Stop the Spread

Time: 45–60 minutes **Suggested grade group:** 6–8

Materials: Stop the Spread Worksheet (see Appendix H on page 48); access to a computer and internet

Lesson: In this activity, students will learn what various agencies are doing to stop or slow the spread of invavive species. Assign each student a state, and then ask them to research what is being done to prevent and control invasive species in that state. Depending on the size of the class, you may want to break the students into small groups of 2-3. Let the students know that multiple agencies within each state are likely involved and that some of them probably work closely together. Some of these agencies may include the local land grant university, such as Utah State University, the local state department of agriculture, such as the Utah Department of Agriculture and Food, or environmental organizations, such as The Nature Conservancy. The students should fill out the Stop the Spread Worksheet as they do their research. After the students have filled out the record sheet, ask for a few volunteers to share their answers with the rest of the class. The students should then turn in their worksheet for credit.

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Image Credits

Fig. 1. Southwest Montana Science Partnership

Fig. 2. (Left); Central Science Laboratory, Harpenden, British Crown, Bugwood.org; (Right) Gyorgy Csoka, Hungary Forest Research Institute, Bugwood.org

Fig. 3. Lori Spears, Utah State University

Appendices

Invasive Species Cards

Forest: Spotted lanternfly

Forest: Asian longhorned beetle

Rainforest: Little fire ants

Rainforest: Feral pig

Invasive Species Cards

Little fire ants were discovered on the Big Island of Hawaii in 1999, most likely traveling on potted plants being shipped from Florida. It is considered to be one of the most destructive invasive ants in the U.S. This species is thought to have cost the U.S. about $5.6 billion per year in damage and control. Little fire ants sting endangered birds and reptiles and interfere with nesting, reproduction, and survival of young. They can also impede agricultural productivity and harm human health by damaging crops and stinging workers. The sting causes a painful burning sensation and itchy welts. These ants are known to protect crop pests, such as aphids and whiteflies, since these pests secrete plant sap the ants eat.

Photo: Eli Sarnat, PIAkey: Invasive Ants of the Pacific Islands, USDA APHIS PPQ, Bugwood.org

The feral pig is a large mammal that is native to the Mediterranean region, central and northern Europe, and most of Asia. After it was introduced to Hawaii in the 1500s by Polynesians as a food source, their population skyrocketed. Feral pigs outcompete native wildlife for resources, trample plants, and destroy the forest floor by uprooting vegetation during foraging. This causes the extinction of native plants, increased soil erosion, and room for the establishment of invasive plants.

Photo: Florida Fish and Wildlife Conservation Commission, Bugwood.org

The spotted lanternfly is an invasive planthopper native to China that was first discovered in the U.S. in 2014 in Pennsylvania. This insect feeds on plant sap from more than 70 plant species, including willow, birch, black walnut, maple, and grapevine. Feeding damage can cause plant wounds and lead to eventual plant death. More so, spotted lanternflies excrete a sugary substance called honeydew that can attract other pests and promote the growth of sooty mold, a gray-black fungus that coats the plant and interferes with photosynthesis.

Photo: Lawrence Barringer, Pennsylvania Department of Agriculture, Bugwood.org

The Asian longhorned beetle is an invasive insect that probably snuck into the U.S. via wood packaging material in the late 1990s. It is native to China and Korea, and can now be found in Massachusetts, Ohio, South Carolina, and New York. This beetle feeds on many tree species such as elm, birch, poplar, maple, ash, horsechestnut, and willow. The immature life stage (larva) feeds on living tissue underneath the bark. Severe larval infestations lead to dead branches and can make tree limbs more likely to break during storms and damage nearby structures. Larval feeding also disrupts nutrient and water flow within the tree, causing the tree to slowly die.

Photo: Donald Duerr, USDA Forest Service, Bugwood.org

Invasive Species Cards

Desert: American bullfrog

Desert: Tamarisk

Freshwater: Zebra mussels

Freshwater: Rusty crayfish

Invasive Species Cards

The zebra mussel is a small freshwater mollusk native to Russia and Ukraine. These mussels probably arrived to the U.S. through ballast water in the bottom of ships in the 1980s. This invasive species can now be found throughout the Great Lakes region, the large rivers of eastern Mississippi, and parts of Utah, Texas, Nevada, and California. Zebra mussels are harmful to freshwater ecosystems because they filter out the algae that native mussels feed on. They can also attach to and kill native mussels, as well as other hard surfaces such as pipes and boats, causing even further problems. Lastly, they can litter beaches, cut feet, and therefore, affect recreation and tourism.

Photo: Amy Benson, U.S. Geological Survey, Bugwood.org

The rusty crayfish is a freshwater crustacean native to the southern U.S. Due to intentional releases and use as bait by anglers, they have taken over some waterways. Since this species has the ability to dominate in extreme conditions, they can survive a wide range of environments. They often outcompete native crayfish for space and forage and can even hybridize with native crayfish, causing the genetic makeup of native crayfish to decline. This species opportunistically feeds on plant and animal matter, often clipping off most of the vegetation in an area and thus changing the food web. A lack of vegetation means less shelter and nesting material for fish and small invertebrates and can cause an increase in soil erosion. As the general ecology of the ecosystem becomes altered, popular gamefish populations may decline, creating a negative impact on anglers.

Photo: U.S. Geological Survey, Bugwood.org

The American bullfrog, native to the eastern U.S., was introduced west of the Rocky Mountains in the 1800s and has consequentially expanded into the southwestern desert region. It is considered one of the most harmful invasive species in the world because it is a generalist predator that preys on other amphibian species and some reptiles. It is thought to have caused the decline of several desert species, such as the leopard frog and gartersnake. Bullfrogs are thought to be carriers of *Batrachochytrium dendrobatidis*, a fungus that causes the infectious disease known as chytridiomycosis, which is considered one of the main causes of global amphibian decline and extinctions.

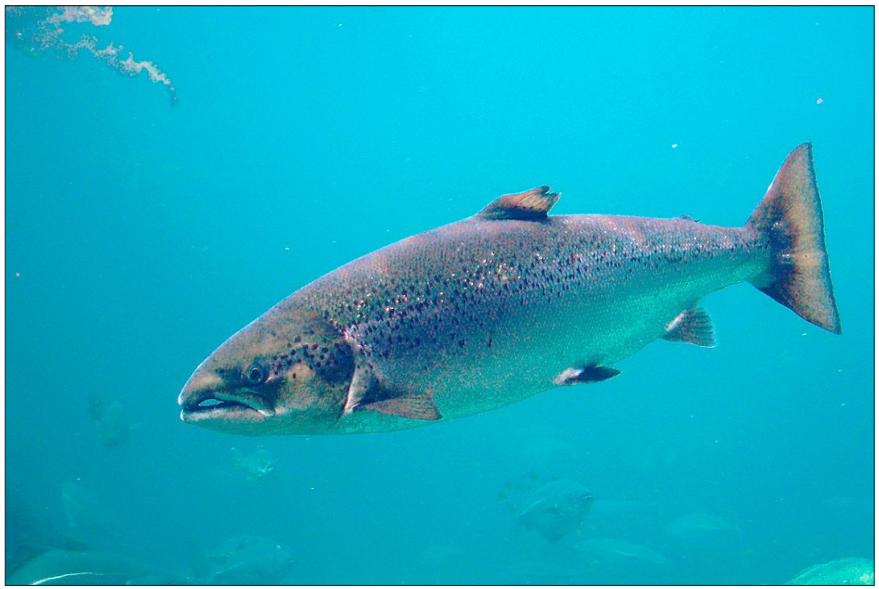
Photo: Russ Ottens, University of Georgia, Bugwood.org

The tamarisk, also known as salt cedar, is an invasive plant that has become well-established in the southwestern U.S. but can also be found in other regions of the country. Originally from Eurasia, this species was introduced because its deep roots help prevent soil erosion and its visually appealing pink flowers are used by landscapers as decorative vegetation. The seeds are able to spread by wind or water, allowing it to establish easily along riparian corridors. The tamarisk competes with native plants for resources and space, and offers little food or other benefits to native wildlife.

Photo: Steve Dewey, Utah State University, Bugwood.org

Invasive Species Cards

Tundra: Atlantic salmon



Tundra: *Lymantria dispar*

Marine: European green crab

Marine: Lionfish

Invasive Species Cards

The European green crab was detected on the U.S. east coast in 1817 and the west coast in the 1980s. This species gets introduced to new areas by hiding in live seafood packages being used as live bait by anglers and ballast water. Marine vessels take on and release millions of tons of water for the ballast to keep the ship stable and this water often contains animals, plants, and fish. When ships dock at a port, they release the ballast water and its contents. European green crabs often prey on clams, oysters, mussels, marine worms, and small crustaceans, putting fisheries and marine ecosystems at risk. One green crab can eat up to 40 half-inch clams, and other crabs its own size, in one day.

Photo: Caleb Slemmons, National Ecological Observatory Network, Bugwood.org

Lionfish are native to the Indo-Pacific but due to accidental releases, have invaded the Gulf of Mexico, the Atlantic, and Caribbean Sea. This species feeds on commercially-important native fish such as snappers and groupers. Lionfish also affect the health of coral reefs by consuming herbivores that limit the growth of algae on coral. Without the herbivores to keep the algae in check, stress is placed on coral reef ecosystems. Coral reefs are vital shelter and protection for many aquatic species. Humans also benefit because coral reefs protect coasts from strong waves and currents and help control the carbon dioxide of ocean water. Coral reefs also attract tourists and sustain fish populations for the fishing industry.

Photo: Rebekah D. Wallace, University of Georgia, Bugwood.org

In the late 1980s, British Columbia and Washington began to import Atlantic salmon from Europe and the eastern U.S. to farm along the Pacific Coast. Farm-raised Atlantic salmon are kept in floating saltwater net pens until they reach market size. However, the salmon often escape the pens or are deliberately released and join schools of Pacific salmon moving into Alaskan waters. Atlantic salmon put pressure on native salmon and trout by competing for spawning and rearing habitat and introducing diseases or parasites. This species can also outcompete native Pacific salmon, an economically important fish, for food.

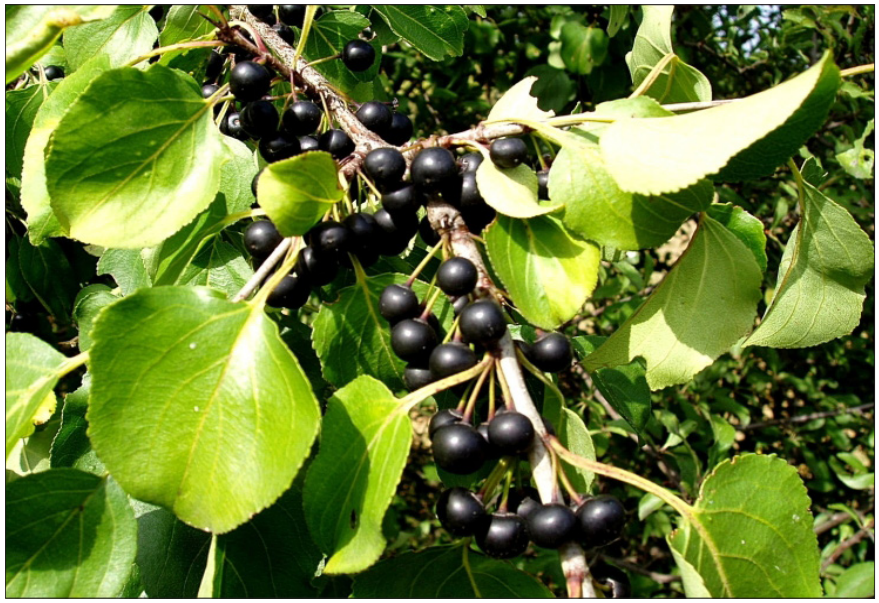
Photo: Hans-Petter Fjeld, CC BY-SA 2.5 <https://creativecommons.org/licenses/by-sa/2.5>, via Wikimedia Commons

Lymantria dispar first arrived in Alaska in 2006. At low densities, this species will not cause a lot of damage; however, during outbreaks that can last 1-5 years, it can destroy the temperate forests they live in. In large numbers, the larvae (immature stage of the adult moth) can defoliate host trees, reduce tree growth, and increase tree mortality. This causes a decline in that area's biodiversity and species composition because of the decline in shelter, food, and resources. This invasive moth can also be found in some forest ecosystems.

Photo: (Main) Haruta Ovidiu, University of Oradea, Bugwood.org; (Inset) Steven Katovich, Bugwood.org

Invasive Species Cards

Prairie: Common buckthorn



Prairie: Garlic mustard

Invasive Species Cards

The common buckthorn is an invasive understory shrub brought to the U.S. from Europe to be used as hedging material. This species forms dense thickets that outcompetes native plants for space, light, and nutrients. Common buckthorn displaces native shrubs and small trees which are important nesting habitat for birds. This shrub is often the host to other pests, such as the crown rust fungus and soybean aphid, that threaten the health of the prairie ecosystem and degrade wildlife habitat. Photo: Jan Samanek, Phytosanitary Administration, Bugwood.org	Garlic mustard is an invasive herb that was introduced to the U.S. in the 1800s for medicine and food. It can often be found along highly trafficked trails since it spreads through mud that contains small seeds. This species negatively impacts native plants by creating highly dense, thick mats that shade and outcompete native species. Garlic mustard also limits forest regeneration by producing a chemical that impedes growth and development of other plants. Photo: Rob Routledge, Sault College, Bugwood.org

Orchard Grower Case Study Worksheet

Name_____ **Date**_____

Instructions: Your apple orchard contains 20 apple trees. The fruit from each apple tree is worth $100 so your orchard is worth $2,000. Codling moths have recently infested your orchard. In Utah, codling moths undergo three generations during the growing season and each generation has the potential to damage your apple crop. Roll the die to determine the number of apple trees you will lose during each generation of codling moth. For each generation, calculate the total number of apple trees that are remaining and the resulting worth of your orchard. At the end of the three rounds of infestations, calculate the final number of apple trees in your orchard and the end worth of your orchard. Then answer the questions at the end of this record sheet. After finishing round 3, answer the questions on the following page.

Starting # of apple trees: 20
Starting worth of orchard: $2,000

Generation 1

Current # of Apple Trees:	# Rolled on the Die:	Remaining # of Apple Trees:	Updated Orchard Value:

Generation 2

Current # of Apple Trees:	# Rolled on the Die:	Remaining # of Apple Trees:	Updated Orchard Value:

Generation 3

Current # of Apple Trees:	# Rolled on the Die:	Remaining # of Apple Trees:	Updated Orchard Value:

Orchard Grower Case Study Worksheet

Name_____ **Date**_____

1. How many apple trees did you lose after three generations of codling moth infestation?

2. What was the total monetary loss of your orchard at the end of the activity?

3. Most apple orchards contain a lot more than 20 trees. For example, a 50-acre farm may contain 500 trees per acre for a total of 25,000 apple trees! Imagine if you had 25,000 trees, but lost 5,000 trees after the first generation of codling moth, 1,000 trees after the second generation, and then 500 trees after the third generation. Assuming that each tree is worth $100, calculate how much money you lost in the season.

4. Invasive species cause monetary loss for growers by damaging crops, but the growers also spend a lot of time and money trying to control invasive species. Let's say that it costs $200 to control codling moth at each generation ($600 total). However, since control efforts aren't always successful, you may only be able to save half of your trees at each generation. Using the information for the 50-acre orchard provided in question 3 above, re-calculate the total number of apple trees after each generation of codling moth and the value of your orchard at the end of the season. When you calculate the value of your orchard, be sure to take into account the $600 you spent trying to control codling moth. What is the final worth of your orchard now?

Ecosystem Services Worksheet

Name_____ **Date**_____

Instructions: Investigate the picture provided by your teacher. This picture will show an economic industry in Alaska. Answer the following questions to identify this economic industry and its ecosystem services.

1. Write down four things found in nature that you see in the picture.

2. Based upon the picture, what is this economic industry in Alaska?

3. How do humans benefit from this type of ecosystem service?

4. What does this ecosystem service need to survive?

5. What impacts would the invasive species have on this ecosystem service? Would this type of economic industry be negatively or positively changed by the invasive species?

Alaska Industry Papers

Industry 1

Examine the images below. The top picture shows an economic industry, whereas the bottom picture shows an invasive species that threatens this industry and the ecosystem services provided by this industry. A description of the invasive species is also included. Discuss this industry and the invasive species with your group and then answer the questions on your Ecosystem Services worksheet.

Atlantic salmon are native to the Atlantic Ocean but have been brought to northern Pacific Ocean waterways for fish farming. This invasive species threatens native salmon populations, an important fisheries staple, by competing for food and habitat and introducing new diseases.

Alaska Industry Papers

Industry 2

Examine the images below. The top picture shows an economic industry, whereas the bottom picture shows an invasive species that threatens this industry and the ecosystem services provided by this industry. A description of the invasive species is also included. Discuss this industry and the invasive species with your group and then answer the questions on your Ecosystem Services worksheet.

Suzan Benz, USDA NASS

L.L. Berry, Bugwood.org

Spotted knapweed is an invasive species native to Europe that is known to outcompete native plant species for space and resources. It also increases soil erosion and is a less desirable forage for livestock.

Alaska Industry Papers

Industry 3

Examine the images below. The top picture shows an economic industry, whereas the bottom picture shows an invasive species that threatens this industry and the ecosystem services provided by this industry. A description of the invasive species is also included. Discuss this industry and the invasive species with your group and then answer the questions on your Ecosystem Services worksheet.

The Norway rat, native to China, threatens Alaskan wildlife and vegetation. This invasive species eats anything smaller than it is, such as small birds and reptiles, and introduces harmful diseases. It consumes seeds and seedlings, thus altering vegetation communities by limiting plant regeneration.

Alaska Industry Papers

Industry 4

Examine the images below. The top picture shows an economic industry, whereas the bottom picture shows an invasive species that threatens this industry and the ecosystem services provided by this industry. A description of the invasive species is also included. Discuss this industry and the invasive species with your group and then answer the questions on your Ecosystem Services worksheet.

USDA Forest Service - Rocky Mountain Research Station - Forest Pathology , USDA Forest Service, Bugwood.org

Haruta Ovidiu, University of Oradea, Bugwood.org

Lymantria dispar is an invasive forest pest from Europe. The larvae (immature stage of the adult moth) can defoliate (remove leaves of) trees. Without its leaves, a tree loses its ability to photosynthesize and thus survive. Fewer trees could cause a huge drop-off in revenue generated from forestry, logging, and the timber trade.

You noticed a hole in your porch screen and fixed it to prevent mosquitoes from coming in your house. Move forward 2 spaces.	Great job! You applied mosquito repellent before a hike. You're safe this round.		You forgot to empty out your kiddy pool so it became a mosquito breeding ground. Move back 1 space.	
				You recently became infected with West Nile Virus and are suffering severe symptoms like body aches and convulsions. You need to rest so skip your next turn.
You forgot to apply mosquito repllent before your soccer game so you got bit by an infected mosquito. Skip your next turn.				Your city just passed a law that prohibits your local mosquito control specialist from spraying insecticide so West Nile Virus is spreading. Move back 2 spaces.
Home Base	A female Asian tiger mosquito laid eggs in your backyard bird bath and now there is an infestation. Move back 1 space.		You wore long sleeves and long pants outside today to prevent mosquito bites. Move forward 2 spaces.	

Chain of Toxins Cards

Zooplankton

You've just found a ton of phytoplankton floating at the top of the water and you're starving! Grab **as many phytoplankton as you can** and place them in your bucket.

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You've just found a ton of phytoplankton floating at the top of the water and you're starving! **Grab as many phytoplankton as you can** and place them in your bucket.

Zebra Mussel

You found a great shore rock to settle on that a lot of zooplankton can be found nearby. As you filter the water, you are able to grab the food bucket from **two zooplankton and may grab as many red poker chips as you can.**

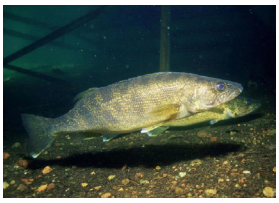
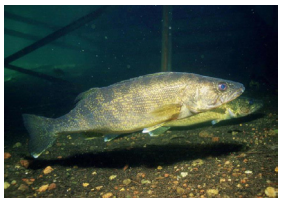
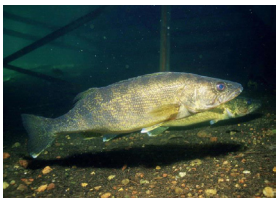
Zebra Mussel

You found a great shore rock to settle on that a lot of zooplankton can be found nearby. As you filter the water, you are able to grab the food bucket from **two zooplankton and may grab as many red poker chips as you can.**

Chain of Toxins Cards

Zebra Mussel  You found a great shore rock to settle on that a lot of zooplankton can be found nearby. As you filter the water, you are able to grab the food bucket from **two zooplankton and may grab as many red poker chips as you can.**	**Zebra Mussel**  You found a great shore rock to settle on that a lot of zooplankton can be found nearby. As you filter the water, you are able to grab the food bucket from **two zooplankton and may grab as many red poker chips as you can.**	**Zebra Mussel**  You have settled on a boat anchor but the boat is constantly moving not giving you a lot of time to filter water to feast. Grab a food bucket from **one zooplankton and as many red poker chips as you can.**
Zebra Mussel  You have settled on a boat anchor but the boat is constantly moving not giving you a lot of time to filter water to feast. Grab a food bucket from **one zooplankton and as many red poker chips as you can.**	**Zebra Mussel**  You have settled on a boat anchor but the boat is constantly moving not giving you a lot of time to filter water to feast. Grab a food bucket from **one zooplankton and as many red poker chips as you can.**	**Zebra Mussel**  You have settled on a boat anchor but the boat is constantly moving not giving you a lot of time to filter water to feast. Grab a food bucket from **one zooplankton and as many red poker chips as you can.**
Zebra Mussel  You have settled on a boat anchor but the boat is constantly moving not giving you a lot of time to filter water to feast. Grab a food bucket from **one zooplankton and as many red poker chips as you can.**	**Round Goby**  You have come across a densely-packed colony of zebra mussels. Grab a food bucket from **two zebra mussels.**	**Round Goby**  You have come across a densely-packed colony of zebra mussels. Grab a food bucket from **two zebra mussels.**
Round Goby  You have come across a densely-packed colony of zebra mussels. Grab a food bucket from **two zebra mussels.**	**Round Goby**  You have already eaten a lot of fish eggs the day before so you aren't that hungry. Grab a food bucket from **only one zebra mussel.**	**Round Goby**  You have already eaten a lot of fish eggs the day before so you aren't that hungry. Grab a food bucket from **only one zebra mussel.**

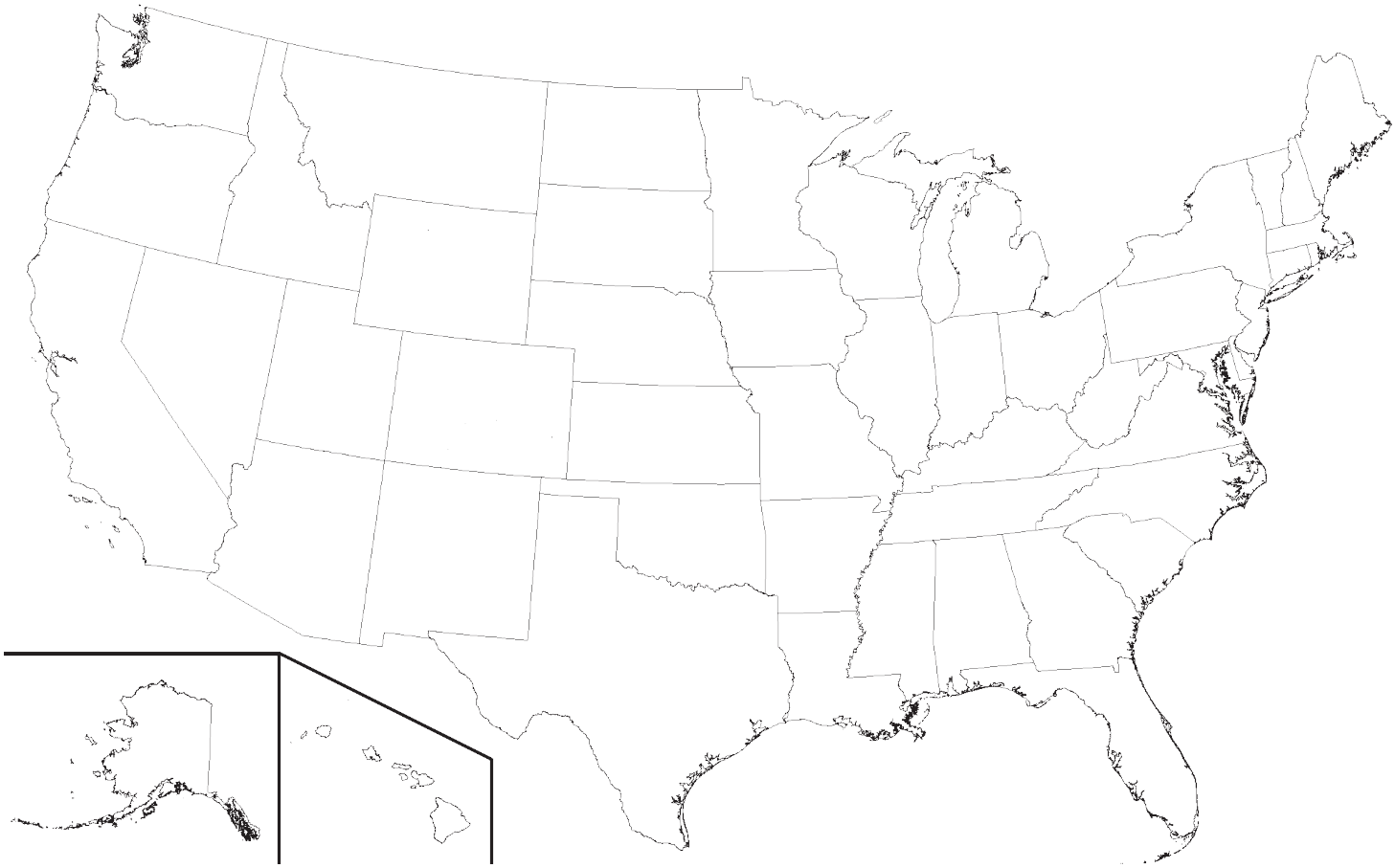
Chain of Toxins Cards

Walleye  You come across a school of round gobies and you haven't eaten in so long! Grab the food buckets from **two round gobies.**	**Walleye**  You come across a school of round gobies and you haven't eaten in so long! Grab the food buckets from **two round gobies.**	**Walleye**  You just missed a school of round gobies swim past you but you are able to track down one of them. Grab the food bucket from **only one round goby.**
Human  You found a great fishing hole with swarms of walleye! Grab the food buckets from **two walleye.**		

Map the Spread Worksheet

Name_____ **Date**_____

Instructions: After you have been assigned an invasive species, research how this species has arrived and spread throughout the U.S. Find the state where the species first invaded, color in this state with a color of your choice. Next, find all other states your invasive species has invaded since its introduction. Draw arrows, in another color, to all these states.



1. What invasive species were you assigned and where does this species originate from?

_____

2. How does this invasive species spread to new areas? Is it known to spread to new areas naturally?

_____

_____

3. What impact does this invasive species have on its non-native range?

_____

_____

Stop the Spread Worksheet

Name_____ **Date**_____

1. List five agencies in your assigned state that work with invasive species.

2. List three to five invasive species some of these agencies work with.

3. Pick one of the agencies and then briefly describe the mission of this agency.

4. What is this agency doing to help prevent invasive species from arriving or establishing in a new area?

5. Do any of the agencies listed in Question 1 work together to help prevent invasive species? If yes, provide an example of how these agencies work together.

EXTENSION

UtahStateUniversity