Biomes

OVERVIEW

In this activity, students are introduced to biomes. They examine climate graphs for 16 locations around the world and group the graphs by similarities to create eight pairs. They then match these to the written descriptions of eight biomes. Finally, students read information about eight plants and determine which biome would be most suitable for each plant.

KEY CONTENT

1. A biome is a region with characteristic climate, geography, and ecological communities of plants and animals.
2. The world can be grouped into a number of distinct biomes.
3. Because biomes are a human construct, there is not perfect agreement on the number and types of biomes found on earth. This unit includes the following biomes: tropical rain forest, desert, savanna, chaparral, temperate grassland, taiga, temperate deciduous forest, and tundra.
4. The abiotic (nonliving) factors in an environment include light, temperature, precipitation, soil, rocks, and minerals.
5. The biotic factors in an environment are related to living things and include organisms, their interactions, and their waste.
6. Some traits are useful in helping an organism survive in a habitat. If the conditions in an environment change sufficiently, or if the organism moves to an entirely different environment, the trait(s) may no longer be useful and the organism will not be as well suited to the conditions.

KEY PROCESS SKILLS

1. Students make accurate interpretations, inferences, and conclusions from text.
2. Students graph and analyze data.

MATERIALS AND ADVANCE PREPARATION

For the teacher
- transparency of Student Sheet 3.1, “Climate Information for Locations”
- Scoring Guide: UNDERSTANDING CONCEPTS (UC)
- Literacy Student Sheet 5, “KWL,” partially filled out in Activity 1, “Ecosystems and Change”

For each pair of students
- set of 8 Biome Organism Cards
- pair of scissors*
- container of white glue or roll of transparent tape*

For each student
- Student Sheet 3.1, “Climate Information for Locations”
- Student Sheet 3.2, “Biomes Match”
- Scoring Guide: UNDERSTANDING CONCEPTS (UC) (optional)

*Masters for Science Skills Student Sheets are in Teacher Resources II: Diverse Learners. Masters for Literacy Skills Sheets are in Teacher Resources III: Literacy. Masters for Scoring Guides are in Teacher Resources IV: Assessment.
TEACHING SUMMARY

Getting Started

- Introduce biomes, and biotic and abiotic factors.

Doing the Activity

- Introduce the UNDERSTANDING CONCEPTS (UC) Scoring Guide.
- Groups of two students work to organize the climate graphs into similar pairs.
- Groups match the climate graph pairs to descriptions of biomes.
- Groups match each organism card to the biome that it seems most suited to.

Follow-up

- (UC ASSESSMENT) The class discusses how regions of the world share certain similarities and that the native species found in a region are adapted to the conditions there.

BACKGROUND INFORMATION

Biomes are regions of the world that share similarities on biotic and abiotic levels. Since the abiotic conditions (especially climate and soil) within a biome fall within a certain range, the traits that help a plant or animal to survive in one location will also help it survive in the same type of biome in a different part of the world. However, having certain traits does not guarantee that an organism can be successfully relocated to the same biome in another part of the world, as such factors as exposure to disease and presence of predators will also have an impact. Because the species in different geographic locations evolved in different ways, the types of species found in different locations vary, even if the biome is the same type. For example, the anaconda is found in parts of the Amazon rain forest, but the python is found in the rain forests of Borneo. Although they are different species, these snakes have similar characteristics (good swimmers, constrictors, can go for long periods without food, need warmth and humidity) and occupy similar habitats in their environments. Both are adapted to the conditions found in the tropical rain forest biome.

The biomes described in this activity represent one way of categorizing ecological regions of the world. Other systems can be found in reference books and through the Internet. Some are more specific and have more biomes, others combine categories in different ways. Since biomes are a human construct, there is not absolute agreement on the definitions and numbers of biomes. However, the concept of biomes is useful in the study of ecology.

Biomes often only include terrestrial ecosystems. Freshwater and marine ecosystems are not always considered by scientists to be part of biome classifications, but are also helpful in the study of ecology and will be addressed in later activities.

Note: The values shown for monthly average temperatures for each location, A through P, are the average of the monthly average high and low temperatures.
GETTING STARTED

1 Use the first paragraph in the Introduction in the Student Book to pose the question: If the cane toad in the case study in Activity 1, “Ecosystems and Change,” had been introduced in Anchorage or Las Vegas would you expect results similar to those seen in Australia?

The class may need some assistance to come to the conclusion that the climates of these two locations are not like that of Queensland. For example, you may need to describe the climate of Queensland for the students—warm to hot, with moderate to high rainfall. Lead students to the idea that for an organism to stand a chance of establishing itself in a location it must be suited to the environment there, including the climate. Have students suggest examples of suitable and unsuitable climates for species—for example, ferns do not live in the desert. Proceed to the next paragraph of the introduction and discuss the definition of a biome. Discuss the difference between biotic and abiotic factors, using precipitation and temperature as examples of abiotic factors. You may want to show your students a variety of world biome maps. For suggestions go to the Science and Global Issues page of the SEPUP website (sepuplhs.org/cgi).

2 Review the definition of evidence. Evidence is information that supports or refutes a claim. Explain that scientists collect information (data) using various tools and strategies, including observation and experimentation. Tell students that in this activity, they will work with climate graphs and biome descriptions to match locations to biomes and organisms to biomes. The consideration of evidence is a key step in decision-making. Throughout this unit and Science and Global Issues, students will collect and analyze information, which they may then apply as evidence to support or refute claims.
DOING THE ACTIVITY

1. Introduce the UNDERSTANDING CONCEPTS (UC) Scoring Guide, and tell the class your expectations for satisfactory work.

4. The pairing for graphs A, E, J, and K may initially be hard to distinguish (see note below). The correct combinations of climate graphs and biomes are shown below:

<table>
<thead>
<tr>
<th>Biome</th>
<th>Climate Graph Matches</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tropical rain forest</td>
<td>D and H</td>
</tr>
<tr>
<td>Desert</td>
<td>L and O</td>
</tr>
<tr>
<td>Savanna</td>
<td>G and N</td>
</tr>
<tr>
<td>Chaparral</td>
<td>F and P</td>
</tr>
<tr>
<td>Temperate grassland</td>
<td>E and K</td>
</tr>
<tr>
<td>Taiga</td>
<td>C and M</td>
</tr>
<tr>
<td>Temperate deciduous forest</td>
<td>A and J</td>
</tr>
<tr>
<td>Tundra</td>
<td>B and I</td>
</tr>
</tbody>
</table>

Note: Students may have trouble distinguishing temperate deciduous forest from temperate grassland, which both have similar temperate climates. The biome information for temperate grasslands states that precipitation tends to be higher in late spring and summer, whereas in the temperate deciduous forest precipitation is more even throughout the year. Graphs E and K show more of a spike in precipitation in late spring/early summer than graphs A and J and therefore are better to group with temperate grasslands. It is not critical that students see clear distinctions in these four graphs. The difficulty they encounter in trying to correctly group these biomes reinforces the fact that biomes are not determined solely by climate, but also by such factors as soil conditions, predominant vegetation types, and specific adaptations of species.

3. **Challenge**

   - How do the characteristics of a biome determine the types of organisms found there?

**MATERIALS**

- FOR EACH PAIR OF STUDENTS
  - set of 8 Organism Cards
  - pair of scissors
  - container of glue or roll of transparent tape

- FOR EACH STUDENT
  - Student Sheet 3.1, "Climate Information for Locations"
  - Student Sheet 3.2, "Biomes Match"

4. **Procedure**

1. Student Sheet 3.1 shows climate information for 16 locations around the world. Each graph contains two sets of data, average temperature and average precipitation per month. Cut the sheet into 16 separate climate graphs.

2. With your partner organize the climate graphs into eight groups by pairing each location with the one that has the most similar climate.

3. Read the descriptions of types of terrestrial biomes on the following pages. Write a short summary of each biome in your science notebook, leaving enough room between them to paste in the climate graphs when you are finished.

4. From the climate descriptions match each biome to one of the pairs of locations that you created in Step 2.

5. In your science notebook, paste each climate graph next to your summary of the corresponding biome.

6. Using the information on the Organism Cards, match each organism to the biome in which the organism might be found. Match each organism to only one biome. Record your matches on Student Sheet 3.2, "Biomes Match," and make sure that all biomes are matched with one organism.

7. In your science notebook include your reasons for matching each organism with the particular biome you chose.

5. After spending time reviewing the pairings with the class—especially the two temperate biomes—ask the students to read the description of each biome in the Student Book and to write summary notes for each in their science notebooks. Be sure students leave at least a half page between each biome summary so that they can affix the appropriate pair of climate graphs in that space.
6. Check that students have correctly matched the climate graphs and the biome descriptions. Hand out the Organism Cards, and allow students to match the organisms (in this case, plants) to the biomes where they seem most suited. Although several plants might survive in multiple biomes, students are asked to make the best match and to only match one plant to one biome. Student Sheet 3.2, “Biomes Match,” will help in this process. If students have difficulty matching the plants, suggest that they first make the more obvious matches and then follow a process of elimination.

See the sample completed Student Sheet 3.2 at the end of this activity for the correct matches.
The savanna has warm temperatures, generally around 25°C–35°C (77°F–95°F) year round. Temperatures are not as constant throughout the year as are those in the tropical rain forest. Total rainfall varies from 500–1,500 mm (about 20–60 inches) per year but is not evenly distributed. There is a long dry season and a rainy season. Trees are scattered, and grasses grow quickly when it rains. The soil is shallow and drains quickly. Fires can occur during the dry season and are important in maintaining biodiversity. When the fires kill small animals, the bodies of the dead animals provide food for other animals, such as birds. Other organisms survive the fires by running away, burrowing underground, or having deep roots. The parts of the plants that burn above ground nourish the soil.

The chaparral receives most of its precipitation as rain during the winter months. Rainfall totals vary from about 200–700 mm (about 8–28 inches) per year. Winter, spring, and fall are generally cool and mild with average temperatures between 10°C and 15°C (50°F–59°F). Summers are warm with average temperatures around 25°C (77°F) although on some days the temperature may rise as high as 40°C (104°F). Some areas of chaparral experience frost at certain times of the year, but there are usually six months or more of frost-free days. The dry summers often cause drought conditions and increase the chance of fires. Vegetation is diverse and sometimes dense. Shrubs, wildflowers, and grasses are common. There are a wide variety of small animals, including amphibians, birds, reptiles, insects, and small mammals.
Temperate Grassland

Temperate grassland experiences a wide range of temperature and precipitation throughout the year. Precipitation is moderate with a yearly average of 500–900 mm (about 20–35 inches). Most rain falls in late spring and in summer. The winter is cold, with average temperatures well below freezing, while summer temperatures average around 25°C (77°F). Five to six months of the year are frost-free. The soil is often fertile and dominated by tall grasses that have adapted to the cold winter temperatures, occasional summer droughts, and periodic fires. The roots of these grasses help to hold the soil together. Many large mammals graze in these grasslands.

Taiga

Taiga is an area of extensive forests where the ground is frozen for much of the year. The winters are long and cold with average temperatures around –15°C (5°F). Precipitation ranges from 300–850 mm (about 12–34 inches) per year. Summers are short, moist, and generally mild enough that the ground thaws. Average temperatures in the summer are around 15°C (59°F), but daily maximum temperatures occasionally rise as high as 30°C (86°F). About three months of the year are frost-free. The range of types of plants that grow here is quite narrow because many plants cannot access the nutrients in the frozen soil. Most of the trees are evergreen conifers. Many different types of mammals live in the taiga, including some very large ones.
Temperate Deciduous Forest

Temperate deciduous forests experience four distinct seasons with a total annual precipitation of 700–2,000 mm (about 28–80 inches). That is spread throughout the year. Temperatures vary a lot over the year and between locations. There are about 140–200 frost-free days each year, depending on the location. Average winter temperatures usually fall to below freezing, and summer averages are around 25°C (77°F). The generally fertile soil, year-round precipitation, and approximately six-month growing period support a wide diversity of plants. Most trees lose their leaves before winter, and some animals hibernate or migrate during the winter months.

Tundra

Very cold temperatures and low precipitation, with yearly totals between 120 and 250 mm (about 5–10 inches), are characteristic of tundra. Winters are long with average temperatures of −30°C (−22°F) or lower. The soil is thin and covers a permanently frozen layer of subsoil called permafrost. The permafrost makes it difficult for plants to extend roots deep into the ground. The permafrost also prevents water from seeping deep into the ground during the short summer when the soil at the surface thaws. Animals usually have fat and fur to help cope with the cold temperatures. Some animals hibernate to survive the harsh winters, and some migrate. Average summer temperatures can reach 10°C (50°F). The growing season for plants is very short with only about two months of the year being frost-free. Plants that do well in tundra tend to grow close to the ground.
FOLLOW-UP

7 It is intentional that the term “extreme conditions” has not been defined for the students. The purpose of Analysis Question 1 is to stimulate a discussion about what “extreme” might mean when considering an organism’s needs. The discussion should include the importance of acclimating to an environment.

8 (UC ASSESSMENT) It may be necessary to help students with part b of Analysis Question 3 if they are unfamiliar with the seasonal differences in the Northern and Southern hemispheres. To do this you might ask them when summer and winter would occur in the location designated in the data table and to examine how the patterns in the climate graphs they have already looked at differ from this climate graph.

Analysis Questions 5 and 6 are UNDERSTANDING CONCEPTS (UC) assessment questions.

Analysis

7 1. Which biome has the most extreme conditions? Explain your answer.
2. Which biome has the most constant conditions over the course of the year? Explain your answer.
3. Make a climate graph using the data in the table below.

Climate Data for Location Q

<table>
<thead>
<tr>
<th>MONTH</th>
<th>TEMP. (°C)</th>
<th>PRECIP (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>29</td>
<td>12</td>
</tr>
<tr>
<td>February</td>
<td>28</td>
<td>41</td>
</tr>
<tr>
<td>March</td>
<td>25</td>
<td>31</td>
</tr>
<tr>
<td>April</td>
<td>20</td>
<td>17</td>
</tr>
<tr>
<td>May</td>
<td>16</td>
<td>19</td>
</tr>
<tr>
<td>June</td>
<td>12</td>
<td>14</td>
</tr>
<tr>
<td>July</td>
<td>12</td>
<td>14</td>
</tr>
<tr>
<td>August</td>
<td>14</td>
<td>9</td>
</tr>
<tr>
<td>September</td>
<td>19</td>
<td>8</td>
</tr>
<tr>
<td>October</td>
<td>23</td>
<td>21</td>
</tr>
<tr>
<td>November</td>
<td>20</td>
<td>19</td>
</tr>
<tr>
<td>December</td>
<td>28</td>
<td>38</td>
</tr>
</tbody>
</table>

a. Which biome is Location Q likely to be in? Explain your choice of biome.
b. What else do the climate data indicate about where Q might be? Explain your answer.

4. Biodiversity is the number of species found in a given ecosystem or area. Based on what you learned in this activity, why do you think levels of biodiversity differ from biome to biome?

5. Review the description of Monarda fistulosa from Procedure Steps 6 and 7 in your student notebook. In which other biome could Monarda fistulosa most likely be found? Explain your answer.

6. Cyclorana platycephala is a frog that is found in Australia. Like all frogs, it needs to keep its skin moist. During periods of drought it digs a chamber in the ground and lines it with mucus, which hardens and seals the chamber from water loss. The frog settles into the chamber, its metabolism slows down, and it becomes inactive. The frog can survive in this state for up to five years. Describe how this trait will determine the types of biome that the frog might live in.
Review the biome descriptions in the Student Book, and point out the following:

- There is a second type of tropical forest called tropical dry forest. Unlike the rain forest where there is year-round precipitation, tropical dry forest has a dry season for several months of the year. These forests, found in India, Mexico, Bolivia, Indochina, and other countries have more deciduous trees than do rain forests, and these trees lose their leaves prior to the start of the dry season.

- Desert environments are not always hot and dry. The following are also deserts:
  - Semiarid deserts, where the summers are warm to hot, quite long, and dry, but the winters bring some precipitation. Examples include parts of Utah, Nevada, and Montana.
  - Coastal deserts where the summers are warm and the winters cool. Precipitation is low but not as low as in the semiarid desert. An example is the Atacama of Chile.
  - Cold deserts, where the temperatures are very cold in winter and the summers are short, warm, and moist. Winter precipitation includes snow. Two examples are Greenland and the Antarctic.
  - Tundra includes alpine tundra, which is found at high altitudes. Here the temperatures can be cold, especially at night. The growing season lasts about six months; plant growth rates tend to be very slow and most growth occurs underground. This tundra occurs above the tree line and can be found in such areas as Mt. Rainier National Park in Washington.

Use the discussion of the investigation and the Analysis Questions to reinforce the concept of biomes and that organisms are acclimated to the environment where they are found. Emphasize that there isn’t universal agreement on definitions of specific biomes. Further, make sure that students understand that biomes are a generalization, and within biomes, particularly in different regions of the world, there is great diversity of ecosystems.

**SAMPLE RESPONSES**

1. Students’ responses will vary. Some may decide that the term “extreme conditions” means very hot or very cold, in which case they would choose desert or tundra as the most extreme biomes. If they looked at temperature variation over the course of a year, they may choose tundra or possibly temperate grassland. If they choose the biome with the most variation in rainfall, they would select savanna.
2. Students’ responses will vary. Some will say that, overall, the tropical rain forest probably has the most stable climate, because there was very little variation in temperature over the course of the year. Although the exact quantity of rainfall in the rain forest varied from month to month, it never decreased to low values. It is also reasonable for students to choose chaparral or desert as having the least variation. Be sure to check their reasoning.

8. Students’ answers will vary. They may include the following responses:
- Some of the biomes have quite similar characteristics and therefore could be classified in various ways.
- The conditions within a biome can vary considerably, and so there are not distinct boundaries that define a biome.
- Some scientists might divide a biome into smaller regions that they consider sufficiently different to be classified as separate and distinct biomes.
- Human classification systems are always open to interpretation.

**REVISIT THE CHALLENGE**

Make sure that students understand that certain traits of organisms enable them to live in the environment where they are found. Emphasize that some organisms may be able to live in a variety of biomes (for example, rats) while others are more restricted in their range (for example, cacti). In addition, conditions in some biomes are more complex and require specialized traits for survival. Through technology humans have also created microclimates, such as the lush green desert environments in Las Vegas, or cacti grown in a school in Alaska.

Return to the KWL chart the class began in Activity 1. Have students suggest items for the “What I Learned” column based on what they have learned in the first three Activities. You will revisit this chart again in Activity 7, “Energy Flow Through an Ecosystem.” A sample KWL appears below.
## Biomes Match

<table>
<thead>
<tr>
<th>Organism</th>
<th>Ideal growing conditions and other information</th>
<th>Best biome match</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Temperature</strong></td>
<td><strong>Precipitation</strong></td>
<td><strong>Soil</strong></td>
</tr>
<tr>
<td>Picea mariana</td>
<td>as low as –60˚C at least 60 frost-free days</td>
<td>380 to 760 mm</td>
</tr>
<tr>
<td>Sorghastrum nutans</td>
<td>needs warm and cold seasons</td>
<td>300 to 800 mm</td>
</tr>
<tr>
<td>Encelia farinosa</td>
<td>no frost</td>
<td>less than 250 mm</td>
</tr>
<tr>
<td>Carex saxatilis</td>
<td>at least 2 months frost free</td>
<td>less than 300 mm</td>
</tr>
<tr>
<td>Chloris gayana</td>
<td>as low as –22˚C at least 6 months frost free</td>
<td>750 to 1,500 mm</td>
</tr>
<tr>
<td>Monarda fistulosa</td>
<td>as low as –35˚C at least 6 months frost free</td>
<td>700 to 1,500 mm</td>
</tr>
<tr>
<td>Rafflesia arnoldii</td>
<td>year-round warm temperatures</td>
<td>year-round precipitation</td>
</tr>
<tr>
<td>Heteromeles arbutifolia</td>
<td>can survive high and low temperatures</td>
<td>200 to 700 mm</td>
</tr>
</tbody>
</table>
OVERVIEW

In this activity students examine several invasive species that have become problems in regions of the United States. They record the species’ effects on the economy, environment, and human health and identify the characteristics that make each of these species a threat. Finally, they take opposing roles in assessing a proposal to introduce a nonnative species into a location.

KEY CONTENT

1. Native species are those that are naturally found in an ecosystem. Since it is impossible for humans to know exactly which species are “natural” to an environment, it is generally considered that a species is native if it is thought to have existed in an environment for thousands of years.

2. An introduced species is one that has been brought into an environment in which it does not naturally occur. Such species are also referred to as nonnative, exotic, or nonindigenous.

3. Not all introduced species succeed in a new environment. If one can easily acclimate to the new environment, it is more likely to become established.

4. If a nonnative species causes harm to the environment, the economy, or human health, it is considered invasive.

5. If a nonnative species displaces a native species from its habitat, it is considered invasive.

KEY PROCESS SKILLS

1. Students make accurate interpretations, inferences, and conclusions from text.

2. Students communicate and defend a scientific argument.


4. Students identify and weigh trade-offs when making a decision.

MATERIALS AND ADVANCE PREPARATION

For the teacher

- Scoring Guide: EVIDENCE AND TRADE-OFFS (ET)

For each student

- Student Sheet 4.1, “Invasive Species Information”
- Literacy Student Sheet 4, “Discussion Web” (optional)
- Literacy Student Sheet 2a, “Writing Frame—Evidence and Trade-offs” (optional)
- Literacy Student Sheet 3, “Writing Review” (optional)
- Scoring Guide: EVIDENCE AND TRADE-OFFS (ET) (optional)

Masters for Science Skills Student Sheets are in Teacher Resources II: Diverse Learners. Masters for Literacy Skills Sheets are in Teacher Resources III: Literacy. Masters for Scoring Guides are in Teacher Resources IV: Assessment.

TEACHING SUMMARY

Getting Started

- Introduce the term habitat by discussing with the class the differences between native, nonnative, and invasive species.

Doing the Activity

- Each student in a group of four reads a different case study of an invasive species.

- Students look for similarities as they compare their notes on four invasive species.

- Groups develop a list of characteristics that increase the likelihood that a species will become invasive.

- Groups analyze two perspectives as they examine a proposal to stop the decline of oysters in Chesapeake Bay.
Follow-up

- (LITERACY) Summarize how a species might become invasive, and discuss the risks and possible benefits of intentionally introducing a nonnative species into an environment.
- (LITERACY) The class conducts a walking debate to discuss the introduction of nonnative oysters into Chesapeake Bay.
- (LITERACY) (ET ASSESSMENT) Students weigh evidence to make a recommendation for or against the introduction of nonnative oysters into Chesapeake Bay.

BACKGROUND INFORMATION

There are many well-publicized examples of invasive species. Species that are considered invasive in the United States include zebra mussels, kudzu, tiger mosquitoes, purple loosestrife, northern snakehead, brown snake, Asian longhorn beetle, and thousands more. (See the Science and Global Issues page of the website—sepulhs.org/sgi—for links to more information.) Nonnative species are introduced intentionally or accidentally into new areas in many ways. Once introduced, a species may eventually die out or it may become established if its traits are advantageous to its living in the new environment and if there is an available habitat. If the species grows and reproduces rapidly, has a mechanism to spread (by flying, wind or water dispersal, attached to boats, etc.), can tolerate a variety of environmental conditions, and can find plenty of food, it is likely to have a significant impact on its new environment. Organisms that are able to outcompete native species by exploiting available resources are likely to displace other organisms, disrupt the balance of the ecosystem, and possibly reduce the biodiversity and sustainability of the area.

Whether a potentially invasive species becomes established doesn’t depend solely on its characteristics; it is also determined by factors within the environment, such as the types and number of other organisms present, limited resources, competition from other species, predators, and disease.
GETTING STARTED

1 Begin the class by having students examine their duckweed populations. Ask them what warning was included in the Student Book as part of Activity 2, “A Population of Duckweed.” Elicit suggestions as to why the warning to not rinse duckweed down the drain is so important. Ask students if they have ever seen duckweed growing naturally in the community. Explain that duckweed is native to Australia and Southeast Asia, and ask what might happen if the duckweed is released into the environment near the school. Make sure that students understand that not all nonnative species become invasive. To be classified as invasive there must be harm to the environment, economy, or human health. Discuss examples of what such harm might look like in each of these three areas.

Invasive Species

Species enter new areas in several ways. In the case of the cane toads, people intentionally introduced them to Australia for pest control. In some cases an organism is carried accidentally with cargo that is being transported from one place to another. In other cases, organisms are carried on the wind and on currents in rivers, lakes, and oceans. If a species is introduced to an area where it is not naturally found, it is referred to as nonnative, and is also known as exotic or nonindigenous. The specific location where an organism lives within an ecosystem is its habitat. This is different from an ecosystem, which refers to all of the biotic and abiotic factors interacting in one location. Within an ecosystem, the population of a native species may decline, and even become locally extinct when an introduced species begins to take over the same role in a habitat. This, in turn, decreases the native biodiversity of the area.

Many crops and animals currently found in the United States are nonnative, including wheat, potatoes, soybeans, honeybees, cows, sheep, and goats. In fact there are approximately 50,000 nonnative species of organisms in the United States. Many species commonly found in the United States are nonnative and invasive, such as the brown tree snake (a), honey bee (b), ice plant (c), and eucalyptus tree (d).
DOING THE ACTIVITY

2. Divide the class into groups of four students and pass out Student Sheet 4.1, “Invasive Species Information.” Sample answers appear in this Teacher’s Edition at the end of this activity.

3. Allow time for each student in the group to share the information about their species that they wrote on the student sheet.

4. Allow a short time for groups to use the similarities to develop a list of characteristics that seem to increase the chance that a nonnative species will become invasive in a new environment. Then, as a class discussion, ask the groups to pool all of their information and develop a list of characteristics and conditions that allow a species to become invasive. This list should include:

   • The ability for the population to increase rapidly
   • Ample nourishment (either because the food source is plentiful in the new environment or because the organism can eat a wide variety of foods)
   • Traits well suited to the new environment
   • Acclimation
   • Adequate defense mechanism against potential predators
   • Absence of predators.

States today, of which about 4,300 are regarded as invasive. For a nonnative species to be considered invasive, it must cause harm to the economy, the environment, or human health. Invasive species often diminish the sustainability of an ecosystem by consuming resources and upsetting the typical interactions between species.

Challenge

How do certain characteristics increase the likelihood that a nonnative species becomes an invasive species?

MATERIALS

FOR EACH STUDENT
Student Sheet 4.1, “Invasive Species Information”
Literacy Student Sheet 6, “Discussion Web”

Procedure

Part A

2. On the following pages are four case studies of particular invasive species. Decide in your group which will read each case study.

3. Use the information from the case studies to complete Student Sheet 4.1, “Invasive Species Information,” as you read about your assigned species.

4. Compare your results with those of the members in your group who studied the other three invasive species. In your science notebook, write down any similarities that you see among the case studies.

5. As a group, use these similarities to develop a list of characteristics that you think increase the potential of a nonnative species to become invasive. Write the list in your science notebook.

6. Follow your teacher’s directions on when and how to share your group’s thinking with the rest of the class. As a class, decide on the characteristics that increase the likelihood that a nonnative species will become invasive.
CASE STUDY 1
The Round Goby

**The Round Goby** is a freshwater fish that grows to between 10 and 25 cm in length. Originally from central parts of Eurasia, it was discovered in the Great Lakes in the 1990s and is thought to have been accidentally discharged in the ballast water from ocean-going cargo ships visiting ports in the Great Lakes. The goby is no longer limited to the Great Lakes and is spreading throughout the region’s rivers and canals.

It can also feed in fast-moving water by attaching itself to the bottom of a stream or river with a suction-like disk on its underside. The round goby is capable of rapid population growth and spawns repeatedly during the summer months, with the female producing up to 5,000 eggs each time. It can live in a variety of habitats and compete with native species for food and space. Often the round goby is the only fish that fishermen see in a section of water. This can make many riverbank or lake-front towns less appealing to visiting sport fishermen, who are trying to catch such fish as trout and salmon. One positive side effect is that the round goby eats another invasive species, the zebra mussel. Native predatory fish, such as the walleye, eat round gobies.

The top map shows locations where the round goby was documented in 2005. The bottom map shows data from 2009.
Leptospirosis can be passed on to humans.

**CASE STUDY 2**

**The Indian Mongoose**

Seventy-three Indian Mongooses were intentionally introduced to the Hawaiian Islands in 1883. They were imported to eat rats that were destroying the sugar cane crops. However, rats tend to be most active during the night, whereas mongooses are most active during the day, so the plan did not work very well. The Indian Mongoose is suspected in causing the extinction of at least one species of bird in Hawaii, and it has killed significant numbers of other native species. As do many other animals, mongooses can carry diseases. Leptospirosis is a bacterial disease that causes symptoms ranging from rashes to kidney and liver failure. Mongooses may transfer it to humans if the animals’ urine mixes with water supplies.

Indian Mongoose (Herpestes javanicus)

The Indian Mongoose grows to around 60 cm (24 inches) and lives as long as 13 years, although 3-4 years is more common in the wild. It is fast moving, and although it mainly eats insects, it will also eat crops, fruits, seeds, birds, eggs, small cats, snakes, frogs, and crabs. Usually solitary creatures, they sometimes live in groups, and their habitat ranges from scrubland to different types of forest to areas where humans live. They breed rapidly, with males able to father offspring when they are only four months old. Each female can produce two to five pups every year.
CASE STUDY 3

**Zebra Mussel**

**Zebra mussels** are native to Eastern Europe. They generally live for four to five years and grow to 5 cm (about 2 inches) in length. The females can reproduce at around two years old and are capable of producing up to one million eggs per year. Adults survive out of water for several days if the temperature is low and humidity is high. Young zebra mussels swim freely and are spread easily by water currents. Adult mussels spread when they attach themselves to objects that have hard surfaces, such as hulls of boats. When the object is moved to a different location, the zebra mussels move with it.

Zebra mussels first appeared in the Great Lakes in 1988, most likely having been flushed into the lakes when ocean-going cargo ships discharged ballast water. Zebra mussels feed by filtering algae and plankton from water, with each mussel filtering up to one liter per day. In areas where there are millions of zebra mussels, two major changes to the ecosystem have occurred: the water has become clearer, which is beneficial for some organisms but not others; and the food for native larval fish has decreased. The clearer water can benefit plants that live on the bottom of the lakes because they have more access to light and thus grow more. Fish that prefer this type of habitat have actually increased in the Great Lakes. The decrease in food for native larval fish causes fewer of the larval fish to survive, creating a food shortage for the animals that feed on these fish. Zebra mussels also attach themselves to native mussels, clams, crayfish, and turtles, sometimes in such great numbers that these organisms have trouble functioning. Several native species of fish eat zebra mussels, but not enough of them to keep the mussel populations down. Sometimes the colonies block water-intake pipes, restricting water flow and causing problems at power plants and water-supply facilities.
INVASIVE SPECIES • ACTIVITY 4

Giant Salvinia

This pond has been taken over by a population of giant salvinia.

GIANT SALVINIA is an aquatic plant native to South America that was first found in the United States in 1995. It forms mats as it floats freely on the surface of slow-moving or still freshwater and reproduces asexually when fragments break off to form clones. The plant can double in size in as little as two days, and its mass can double in a week. As the mats grow they form layers as much as a meter thick. The buds of giant salvinia can withstand dry conditions, and the plants can tolerate freezing air temperatures—but not ice—on the surface of the water where they grow.

Giant salvinia can spread on moving water or by clinging to boats and other recreational craft. A single plant can spread over an area of more than 100 sq km (about 40 sq mi) within a three-month period.

The floating mat formed by giant salvinia blocks sunlight from the water and prevents oxygen mixing at the surface. This change in conditions reduces the number and variety of microorganisms living in the water, which in turn means less food for the organisms that feed on them. The rapid spread of giant salvinia can threaten crops, such as rice, and clog irrigation and drinking-water lines. The thick mats can clog waters to the extent that swimming, boating, and fishing become impossible. The mats are also breeding grounds for mosquitoes.
One of the goals of *Science in Global Issues* is to teach students that:

1. decisions often involve trade-offs.
2. identifying trade-offs involves analyzing evidence.

Explain to students that in this unit they will make several decisions about fisheries and ecosystem change. In this activity students review the trade-offs involved in the possible introduction of a nonnative species to aid in the recovery of a collapsed oyster fishery. In a decision involving trade-offs, something is given up to gain something else. Since many decisions involve trade-offs, it is important for students to understand that a perfect choice is often not possible. It is possible, however, to recognize and analyze the trade-offs associated with each decision. For example, when asked, “Paper or plastic?” at a store checkout counter, most shoppers make the choice quickly. But there are several trade-offs attached to choosing paper or plastic. A shopper who chooses paper over plastic may do so to avoid generating plastic waste or using up petroleum resources. In requesting the paper bag though, they are contributing to other environmental problems such as increased water and energy usage, and the higher amounts of solid waste and CO₂ emissions associated with making paper bags. Neither choice is particularly beneficial for the environment, and both choices have a downside. Identifying the trade-offs helps clarify the reasoning that is being applied to make a decision, and the strength of the evidence relevant to making the most informed decision.

---

**Part B**

In this section you will read about the benefits and risks of the possible introduction of a nonnative species to try to replenish a fishery. The balance between these benefits and risks is known as a trade-off. A trade-off is an exchange of one thing in return for another, giving up something that is a benefit or an advantage, in exchange for something that may be more desirable.

6. Read the summary of a report about the possible introduction of nonnative oysters into Chesapeake Bay.

7. Use a Discussion Web to analyze the statement “nonnative oysters should be introduced into Chesapeake Bay as soon as possible.” In the Discussion Web, make sure to discuss the characteristics of invasive species the class listed in Step 5. For the Discussion Web, have two members of your group take the role of fishermen who make their living from harvesting oysters in the Bay, and two should act as conservationists who wish to return the Bay to its original state.

8. When you have completed the Discussion Web, with your same-role partner, compare your comments and conclusions with the members of your group who took the other role. In your science notebook, write down any questions that you would want answered before making a final decision on whether to introduce the nonnative oyster species into the Bay.

9. Under your teacher’s direction, discuss as a class the questions that you recorded for Step 8.

---

To further explore trade-offs, brainstorm with the class a list of decisions they make every day that involve trade-offs. Choose one and talk through the associated trade-offs of deciding one way or another. This practice will familiarize students with ways of identifying and considering trade-offs for this and subsequent activities.
6  (LITERACY) Instruct students to complete Student Sheet, 4.2, “Discussion Web: Oysters in Chesapeake Bay.” This literacy strategy provides a framework for students to discuss and organize their ideas about introducing nonnative oysters to Chesapeake Bay. Encourage students to focus on applying evidence from the activity or the unit as they fill out the student sheet. For more information on discussion webs, see Teacher Resources III: Literacy. Each member of the group should first read the summary of the Chesapeake Bay oyster situation in the Student Book. The groups then split into pairs with two students taking the role of conservationists and the other two adopting the role of fishermen. Each pair should complete the Discussion Web based on the perspective that would be associated with their role. In the center box they write the question, “Should nonnative oysters be introduced?” On the left side the heading should be “Conservationists” and on the right “Fishermen.” Students list evidence on the appropriate side. A sample completed discussion web is shown below.

7  Members of each group share their completed Discussion Webs within their groups and generate a list of questions they have about the proposal to introduce the nonnative oysters into the bay. Questions from Procedure Step 8 might include what the likelihood is of these nonnative oysters bringing disease into the bay, how likely the oysters are to spread outside the bay, whether the oysters would crowd out and eventually replace the native oysters, and if steps have been taken to reduce the habitat destruction and to improve water quality. Allow time to discuss these, and other questions, with the class. Bring up the dilemma of waiting until all questions have been answered, which could be so long that the bay could suffer irreversible damage, or acting before the problem and potential solution are fully understood. Remind students about the problems that the Indian mongooses and cane toads were supposed to solve. The proposal to introduce nonnative oysters to Chesapeake Bay was in fact rejected in the middle of 2009 after eight years of study. So as to avoid influencing the students, share this information with the class only after the discussion and debate has taken place.

---

**Conservationists**

**Should nonnative oysters be introduced?**

**Fishermen**

- Introducing a foreign species will make the bay less like the way it was not more like it.

- Nobody knows what impact the introduction of non-native oysters will have on the native oysters and other species found in the bay.

- The fact that the non-native oysters breed quickly indicates that it could become invasive if introduced.

- The non-native oysters may bring diseases with them.

- Introducing non-native oysters will increase the number of oysters in the bay since the non-native oysters breed and grow quickly.

- Having more oysters will mean more jobs and more income for families and businesses that depend on the oyster catch.

- The presence of more oysters will lead to more filtering of the water in the bay. This will help to improve the water quality of the bay and will help increase the native oyster population.

- The non-native oysters have some resistance to the diseases that killed many native oysters.
LITERACY You can extend the debate and prepare students for the written assessment by conducting a walking debate. See Teacher Resources III: Literacy for more information. Designate one corner of the room as “introduce nonnative oysters” and a second area of the room as “do not introduce nonnative oysters.” Have students stand in the place that they believe is the best action. (If most of the students already agree on a particular option, you may want to assign some of them to the other options to foster the skills of debate and evidence analysis.)

Have students in each area talk among themselves to create a convincing, evidence-based argument that will bring students from the other areas to their own area. They can also develop questions to ask the other groups. Have each group present their argument and respond to any questions. After all groups have spoken, each student individually decides which was the most convincing argument by moving to the area that represents his or her final position.

Possible evidence students may include in their responses for each position is shown in the table at right.

### Sample Student Evidence

<table>
<thead>
<tr>
<th>Conservationists (do not introduce nonnative oysters)</th>
<th>Fishermen (introduce nonnative oysters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• nonnatives do not grow well when competing with other species</td>
<td>• grow more rapidly than native oysters</td>
</tr>
<tr>
<td>• might outcompete native oysters and prevent their recovery</td>
<td>• can survive a wide range of conditions</td>
</tr>
<tr>
<td></td>
<td>• are resistant to diseases that kill native oysters</td>
</tr>
<tr>
<td></td>
<td>• filter the water</td>
</tr>
</tbody>
</table>

Students may include additional evidence from other activities or outside sources as appropriate.
FOLLOW-UP

LITERACY (ET ASSESSMENT) Use the Analysis Questions to check that students have understood the difference between native, nonnative, and invasive species, and why some nonnative species become invasive while others don’t. Use Analysis Question 4 to introduce the EVIDENCE AND TRADE-OFFS Scoring Guide, and discuss with the class what would be required for a Level-3 response to this question. This question is particularly suited to assessing students on their analyses of options and perspectives, and on supporting a position. To help students with this question you may wish to pass out Literacy Student Sheet 2a, “Writing Frame—Evidence and Trade-Offs.” This sheet provides a literacy strategy that gives students a structure for communicating their ideas. It helps students organize their ideas into coherent written responses. More information about the use of the writing frame literacy strategy is in Teacher Resources III: Literacy. A sample student Level-3 response is shown under Sample Responses item 4 at the end of this activity.

After students have written their responses, but before you score them, have students participate in a peer writing review. A peer writing review presents a series of questions by which students evaluate each other’s writing. It can be especially useful in guiding them to write a complete and coherent response. Students can compare others’ responses to the review questions or revise their own writing. Literacy Student Sheet 3, “Writing Review,” lists questions and includes space for students to respond. See Teacher Resources III: Literacy for more information on the peer review.

EXTENSION

Explain that invasive species are a concern for every state in the United States and for all countries around the world. Every year hundreds of millions of dollars are spent on prevention and treatment programs and on dealing with the consequences of invasive species. Have students research what the scope of the invasive species problem is in their own state.
SAMPLE RESPONSES

1. Invasive species tend to tolerate a wide range of conditions, breed rapidly, and consume large quantities of food, sometimes eating a wide variety of food sources.

2. If an ecosystem were similar to the native ecosystem of a species, it would probably be easier for it to invade. Scientists might refer to descriptions of biomes to predict where a species might become invasive. For example, if the species is found in a new location that is the same biome as its native ecosystem, it is probably more likely to become invasive.

3. As described in the case studies of the Indian Mongoose in Hawaii and the cane toad in Australia, introducing a nonnative species to control another species does not always work. Even when it does work, other native species could be adversely affected. If the population of the introduced species increases too much, it can cause competition for food and space with native species. The nonnative species may also introduce diseases that might harm or kill native species.

4. (LITERACY) (ET ASSESSMENT) Students’ answers will vary. A complete and correct response will include a description of the data and any trends, and an interpretation of why the trends occurred.

Sample Level-3 Response

There is a lot of discussion about the issue of introducing nonnative oysters to Chesapeake Bay. My decision is that the nonnative oysters should be introduced to the bay. My decision is based on the following evidence:

First, it will increase the number of oysters in the bay. The nonnative oysters breed and grow quickly and can grow in the poor water conditions that presently exist in the bay. Second, having more oysters will mean more jobs and more income for families and businesses that depend on the oyster catch.

Third, the presence of more oysters will lead to more filtering of the water in the bay. This will help to improve the water quality of the bay and will help increase the native oyster population.

Some trade-offs of my decision are that we do not know all of the effects of introducing the nonnative oyster into the bay, especially how it will affect other organisms and whether it will stay in the bay or spread into other areas.
REVISIT THE CHALLENGE

The challenge question asked what characteristics would increase the likelihood that a nonnative species would become an invasive species. The activity provided much of the answer to this question but a more complete answer will involve extending the final discussion a little further. As part of the summary discussion with the class, make sure that you include the following points:

• The characteristics common to many invasive species include rapid reproduction (for example, short gestation period, high number of offspring, ability to breed from a young age, ability to reproduce sexually and asexually), fast growth, nonspecific food needs, tolerance of a wide range of conditions, and ability to disperse to new areas.

• The environment plays a role in whether an organism can become established, in terms of whether there are sufficient resources and if there are predators or other mechanisms by which the growth of a population might be controlled. Essentially if the organism is able to exploit a habitat in the new environment, it can become established.

• If this habitat is occupied at the expense of other organisms in the environment, the species is regarded as invasive.

• If the organism damages resources that support the local economy, it is classed as invasive (for example, reducing fishing, farming, and hunting). Finally, if an introduced organism brings disease to the local people, it is considered invasive (for example, the Asian tiger mosquito spreading yellow fever or the Indian Mongoose being a vector for *Leptospirosis*).

Numerous efforts have been made to improve the Chesapeake Bay ecosystem and to restore the oyster resources of the bay. One proposal made in the early years of this century involved the potential introduction of a species of oyster that is native to the coasts of Asia, *Crassostrea ariakensis*. The hope was that this species would thrive, and filter the polluting algae from the bay’s waters, improving conditions sufficiently for native oyster populations to begin to recover.

*C. ariakensis* is larger and tends to reproduce more quickly than the native oysters (*Crassostrea virginica*). It also grows much more rapidly than native oysters during the winter months. It can be harvested and sold and would provide a much-needed economic boost to the oyster fishing industry.

*C. ariakensis* can survive in a wide range of conditions, including those currently encountered in Chesapeake Bay. However, recent research has indicated that the nonnative species does not reproduce or grow as well when space is limited, for example when it has to compete with other species. *C. ariakensis* has been shown to have some resistance to the diseases that killed many of the native oysters, but they are susceptible to, and may carry, other diseases and parasites. These diseases, however, are not currently common in the Chesapeake Bay. The nonnative Asian oysters that would be introduced to the bay through the proposal would come from oyster farms in Oregon.
# Invasive Species Information

<table>
<thead>
<tr>
<th>Name of organism</th>
<th>Round Goby</th>
</tr>
</thead>
</table>
| **Effects on economy** | decreases types and numbers of certain fish  
| | reduces opportunities for fishermen to fish for trout and salmon, thereby reducing the income of the area |
| **Effects on environment** | competes with native fish  
| | seems to decrease biodiversity  
| | eats lots of food  
| | eats zebra mussels |
| **Effects on human health** | none mentioned |

## Information about breeding, reproduction, and lifecycle
- rapid population growth (5,000 eggs per spawn)  
- aggressive during and after spawning  
- reproduces several times during the summer

## Information about food sources and eating habits
- consumes large quantities of food  
- eats a wide variety of food  
- can hunt in the dark

## Information about habitat and methods of spreading
- found in fresh water  
- lives throughout the Great Lakes  
- spreads through rivers and canals

## Other information
- accidentally introduced in ships’ ballast water  
- food for walleye
## Invasive Species Information

<table>
<thead>
<tr>
<th>Name of organism</th>
<th>Indian Mongoose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effects on economy</td>
<td>eats crops that otherwise might be sold</td>
</tr>
<tr>
<td>Effects on environment</td>
<td>eats many native species</td>
</tr>
<tr>
<td></td>
<td>decreases diversity</td>
</tr>
<tr>
<td></td>
<td>some native birds have become extinct</td>
</tr>
<tr>
<td>Effects on human health</td>
<td>carries disease (Leptospirosis, rabies)</td>
</tr>
<tr>
<td>Information about</td>
<td>breeds rapidly</td>
</tr>
<tr>
<td>breeding, reproduction,</td>
<td>at 4 months old males can father pups</td>
</tr>
<tr>
<td>and lifecycle</td>
<td>females can have 2 to 5 pups per year</td>
</tr>
<tr>
<td>Information about</td>
<td>eats a variety of foods</td>
</tr>
<tr>
<td>food sources and eating habits</td>
<td></td>
</tr>
<tr>
<td>Information about</td>
<td>can live in a variety of habitats</td>
</tr>
<tr>
<td>habitat and methods of</td>
<td>generally lives alone but can live in groups</td>
</tr>
<tr>
<td>spreading</td>
<td>can live near humans</td>
</tr>
<tr>
<td>Other information</td>
<td>intentionally introduced to reduce rat populations in sugar cane fields in Hawaii</td>
</tr>
<tr>
<td></td>
<td>didn’t protect sugar cane as intended</td>
</tr>
<tr>
<td></td>
<td>generally lives up to 4 years in the wild</td>
</tr>
</tbody>
</table>
## Invasive Species Information

<table>
<thead>
<tr>
<th><strong>Name of organism</strong></th>
<th>Zebra Mussel</th>
</tr>
</thead>
</table>
| **Effects on economy** | blocks water pipes  
decreases some fish stocks, increases others |
| **Effects on environment** | clears water  
decreases food for some native fish  
can harm organisms, such as native mussels, clams, crayfish, and turtles |
| **Effects on human health** | none mentioned |
| **Information about breeding, reproduction, and lifecycle** | females reproduce at 2 years  
up to 1 million eggs per year |
| **Information about food sources and eating habits** | are filter feeders that eat algae and small animals  
filter 1 liter of water a day |
| **Information about habitat and methods of spreading** | can attach to boat hulls and other solid objects  
spreads in water currents  
can survive out of water for a few days |
| **Other information** | introduced accidentally in ships’ ballast water |
# Invasive Species Information

<table>
<thead>
<tr>
<th><strong>Name of organism</strong></th>
<th>Giant Salvinia</th>
</tr>
</thead>
</table>
| **Effects on economy** | threatens some crops  
clogs irrigation and water lines  
clogs waterways—interferes with transportation |
| **Effects on environment** | blocks sunlight and prevents oxygen moving through the water surface  
reduces microorganisms and the organisms that feed on them |
| **Effects on human health** | can be a breeding ground for mosquitoes, which can carry disease |
| **Information about breeding, reproduction, and lifecycle** | can clone (asexual reproduction)  
biomass can double in 1 week  
1 plant can cover 40 square miles within 3 months |
| **Information about food sources and eating habits** | photosynthesis  
buds can withstand dry conditions  
can tolerate freezing air temperatures |
| **Information about habitat and methods of spreading** | slow-moving or still water  
spreads by water movement or by boats |
| **Other information** | forms large, thick mats very quickly  
can increase mosquito breeding |