Disruptions in Ecosystems
Ecosystem Interactions, Energy, & Dynamics

CHAPTER 1
Wolves in Yellowstone

CHAPTER 2
Ecosystem Models

CHAPTER 3
Interactions Between Populations & Resources

CHAPTER 4
Zebra Mussels

CHAPTER 5
Designing Solutions

Third Field Test Version
Middle School Unit aligned with the Next Generation Science Standards

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In this unit you have seen many ways in which humans interact with ecosystems. For example in chapter 4 you learned that we receive ecosystem services, such as food, water, and recreation. Throughout the unit you have also learned that humans can cause disruptions to ecosystems. Many disruptions create a threat to the biodiversity of the ecosystem. Although humans cause environmental problems, we also have the ability to solve them. Scientists work to make sense of phenomena. Engineers use this understanding to design solutions. In doing so it is possible to develop solutions to lessen the negative impact that humans have on the earth.

In this chapter you will examine more environmental problems. However, this time you will make decisions. You will consider cause and effect relationships as the decisions you make have environmental consequences. You will also act as engineers. As engineers you will develop and use criteria to evaluate solutions to environmental problems. Finally, you will design your own solution to a problem.
Throughout this unit you have encountered various environmental problems. In this chapter you will continue to look at such problems, but you will also consider what can be done about them. The first problem to solve involves insects, as described in the story below.

Holly sat in the shade and watched her parents talking. She couldn’t hear everything that they said but she knew what they were talking about. In all the years that she had lived on the farm, she had never seen them so worried. She turned to look at the fields that surrounded the house. Holly felt sad as she saw the large areas where the crops were damaged or dead. She knew that her parents were discussing what they could do about the insect that was damaging the crops. Holly’s parents had bought the farm when she was five years old. Now that she was in middle school, it seemed that she had lived on the farm all her life. Jumping to her feet, Holly moved towards her parents to join in the discussion.

**Guiding Question**

What are some of the ways to deal with an insect problem?
**Materials**

For each student:
- Handout 5.1-1, “Control Methods”

**Process & Procedure**

1. Read Holly’s story at the beginning of this activity.
2. In your group, brainstorm a list of questions that Holly might ask her parents to learn more about the insect problem affecting the family farm.
3. Follow your teacher’s directions to discuss these questions with the rest of the class.
4. In your group, discuss possible ways of solving the insect problem.
5. Share your group’s ideas with the class.
6. In your group, read about the four possible solutions in Handout 5.1-1, “Control Methods.”
7. Discuss each solution and make a list of the advantages and disadvantages of each.
8. As a group, recommend the solution that you believe is the best one for Holly’s family. Make sure that each person in your group can explain why you chose this solution.
9. Follow your teacher’s directions to discuss your recommended solution with the class.

**Analysis**

1. What factors did you consider when deciding which solution to recommend?
2. What other information would have been useful when you were examining solutions?
3. Holly’s story is based on a real-life problem. Your teacher will give you more information about the problem and the solution that was tried. Describe how the solution relates to an environmental problem that you have studied in this unit.
In the previous activity you discussed an environmental problem on a farm. Insects were destroying crops which meant that the family was losing money. The family was unhappy with the situation and needed to decide on a solution. The decision on dealing with the insect problem had many effects. Some of the effects were unexpected. In this activity you will play the role of managers of connected environmental areas. In your groups you will make decisions about changes to the areas. Your decisions will affect the stability of the areas through both expected and unexpected effects. You will keep track of how your decisions affect the environment, money, and how people feel. Your goal is to manage your area so that it is in a better condition at the end of the activity than it was at the beginning.

**Guiding Question**

How can we balance human needs with those of the environment?
Materials

For each group of 4 students:

- set of Round 1 event cards
- set of Round 2 event cards
- set of Round 3 event cards
- map

For each student:

- Handout 5.2-1, “Score Sheet”

Process & Procedure

1. As a group, decide who will manage each of the four areas on the map—Forest, Lake, River, and Gulf.

2. On Handout 5.2-1, circle the area that you manage.

3. Choose a player to begin and have that player take a card from the Round 1 event card stack.

4. One person in your group should read aloud the Action item at the top of the card.

5. The other members of the group should discuss and predict how each decision would change the environmental, money, and happiness scores.

6. As a group, make a decision on which action to take.

7. In the row labeled “Round 1, Turn 1” of the table on Handout 5.2-1, “Score Sheet,” write down the new number of points in each column after adding or subtracting points based on the decision you made in Step 6.

8. Repeat Steps 4 to 7 by having a different player take a Round 1 event card.

9. Continue to have each player in your group take a Round 1 event card and add or subtract the points in each column each time.

10. After four turns using Round 1 event cards, repeat Steps 3 to 9 using the Round 2 event cards.
11. Repeat Steps 3 to 9 using the Round 3 event cards.

12. In your science notebook, write down your point total at the end of the three rounds.

Analysis

1. Describe an example of a cause and effect relationship that occurred during the game.

2. Describe any patterns that you saw in the way that the environmental, money, and happiness points changed.

3. Explain how an event in one area could affect another area.

4. Do you believe that your area was in a better condition at the end of the game than at the beginning? Explain the reasoning behind your answer.

5. How difficult was it to balance human needs with those of the environment? Explain your answer using examples from the activity.
**Explain: Designing a Solution**

Throughout this unit you have seen examples of how human activity has had an impact on the health of the environment. In the previous activity you modeled making decisions that affected communities across different but related ecosystems. Sometimes you tried to agree on solutions to problems such as relieving traffic congestion, restoring low fish stocks, and building more housing. A good solution works for people and for the environment. It also does not create problems in the future. In this activity you will use a framework to examine and design solutions to environmental problems.

**Guiding Question**

What factors should be considered when choosing or designing a solution to an environmental problem?
Materials

For each group of four students:
- 1 set of two Insect Solution cards

For each student:
- Handout 5.3-1, “Analyzing the Insect Solutions”
- Handout 5.3-2, “Designing a Solution”

Process & Procedure

1. Follow your teacher’s directions to complete the reading below.

Designing a solution to an environmental problem

Engineers design solutions to problems. However, the aim of engineering is not just to design a solution, but to design the best solution. Before designing a solution, engineers will identify criteria and constraints. **Criteria** are the desired features of the solution. **Constraints** are limits that apply to solving the problem. A solution can have many criteria and constraints. This can make designing the solution complicated.

As you saw in the previous activity, it can be difficult to satisfy the needs of people and those of the environment. When considering criteria related to people, it is useful to look at the social and economic impacts. **Economic** impacts are often related to money. They can be positive, such as earning more money. They can also be negative, such as reduced income or higher costs for people in an area. **Social** impacts are often related to the quality of life. They can include factors such as the health and safety of residents, the standard of living, and opportunities for work and leisure. An important social consideration is whether a solution is fair to different groups of people. One way of analyzing solutions to environmental problems is to consider how well they meet economic, social, and environmental needs.
2. Your teacher will assign your group one of the proposed solutions to the insect problem from Activity 1 of this chapter. Complete your row of Handout 5.3-1 by identifying possible economic, social, and environmental impacts of your assigned solution.

3. Meet with another group that was assigned the same solution. Compare the impacts that you recorded on Handout 5.3-1.

4. Follow your teacher’s directions to share the discussion that you had with the other group. Use the information from other groups’ reports to complete the other rows on Handout 5.3-1.

5. One pair of students in your group should read Insect Solution card A. The other students in your group should read Solution card B.

6. Discuss the criteria and constraints listed on the card with your partner.

7. Select the insect solution that best fits the criteria and constraints on your card.

8. Tell the other students in your group which solution you selected. Make sure to explain why you chose that solution.
9. As a group, discuss how the criteria and constraints affected the choice of solution.

10. Use Handout 5.3-2, “Designing a Solution” to design your group’s solution to the insect problem. Make sure to provide your reasoning to justify why you think a solution or combination of solutions is the best choice.

11. Follow your teacher’s directions in sharing your solution and your reasoning with the class.

12. As a class, discuss how to make a better solution. Include any changes that you would make to the criteria or to the proposed solutions.

**Analysis**

1. How do criteria and constraints affect the development of a solution?

2. Which types of criteria might be in competition with one another? Suggest reasons why.

3. Scientific knowledge is valuable when making decisions because it can describe the consequences of actions. However, science is not usually the only consideration when making a decision. Explain why, using an example from a problem that has affected your own community.
Humans rely upon ecosystems in many ways. They supply us with resources such as food, shelter, energy, and even the oxygen that we breathe. They also provide enjoyment and income for people. Using resources can also threaten the health of the ecosystem. In some cases a problem can become so bad that the environment will not recover by itself. In such cases, a solution is needed. Ideally, engineers would design solutions that preserved biodiversity and ecosystem services. After a solution is put in place it must be monitored to see if it is working. In this activity, you will examine several environmental issues and evaluate possible solutions.

Guiding Question
How can we evaluate solutions to decide how well they might work?

Materials
For each group of 4 students:
- Handout 5.4-1,”Possible Solutions”
**Process & Procedure**

1. As a group, examine the environmental problem assigned by your teacher.

2. In your science notebook, write down the cause of the problem and describe its effects.

3. Brainstorm a list of possible solutions with your group members.

4. Identify any constraints and criteria that you wish to apply to your solution.

5. Rank your list of solutions from best to worst.

6. Meet with the other group that has been assigned the same environmental problem. Compare your lists of possible solutions.

7. Explain your criteria, constraints, and ranking to the other group.

8. Your teacher will give your group Handout 5.4-1, “Possible Solutions,” which includes possible solutions for your environmental problem. Discuss the solutions and evaluate them against your criteria and constraints.

9. As a group, make a recommendation for a solution. You may use one of the solutions provided by your teacher, one of those suggested by your group, or a combination of different solutions.

10. Meet with the other group again to discuss the solution that you chose. Make sure to explain the reasoning behind your choice.

11. Follow your teacher’s directions to share your discussions with the class.

**Analysis**

1. Describe how your criteria were similar to that of the other group who had the same environmental problem.

2. Describe how your criteria were different from that of the other group who had the same environmental problem.

3. Can environmental problems be solved by technology alone? Explain your answer.
Environmental Problem 1

Coral reefs are very important to the health of the oceans as they are home to almost 25% of all marine organisms. They are also important to communities as they provide protection from erosion from storms. They provide ecosystem services such as food, recreation, and employment. One threat to coral reefs is the crown-of-thorns sea star, a large starfish that preys on hard coral. It is native to coral reefs in the Indian and Pacific Ocean regions. Some coral species grow quickly and others grow slowly. When the crown-of-thorns feeds on the faster growing coral it provides an opportunity for the slower growing species to establish itself. This increases the biodiversity of the coral reef. During the warmer months each female can produce millions of eggs. Predators of the adult crown-of-thorns include several species of fish. In some coral reefs, overfishing of these predators has led to large increases in the numbers of crown-of-thorns starfish. When this occurs, much more of the reef is eaten by the starfish. In some cases up to 90% of a reef can be destroyed by the crown-of-thorns starfish.
Environmental Problem 2

In a corner of an island in Southeast Asia, there is a village next to a lake. Near to the lake is a large area containing mountains and forest. Although not a national park, the land in this area is protected from development. Most of the people in the village are farmers. There are few employment and educational opportunities. Most people have little money. The lake is used for drinking water and for electrical power generation for the region. The fish in the lake are an important and inexpensive food source for families in the region. Recently, villagers have been going into the protected area to hunt animals and cut down some of the trees. The wood from the trees can be used for fuel and can be sold. Some of the farmers in the village have also cut down trees in the protected area so that they can expand their farms to grow more food. All of these actions have led to a decrease in the biodiversity of the forest. The removal of the trees has also led to increased erosion of the soil in the forest. The soil is being washed into the lake which is increasing the sediment there. This is affecting the food web of the lake and also the quality of the drinking water.

The area in front of the picture used to be a forest until the trees were cut down and removed.
Environmental Problem 3

Yellowstone Lake is the largest body of water in Yellowstone National Park. It is a very large (350 km²) freshwater lake with an average depth of 42 m. More than 140 rivers and streams flow into Yellowstone Lake. The Yellowstone River is the largest outflow of water from the lake, eventually reaching the Missouri River. At the present time, no zebra mussels have been spotted in Yellowstone Lake but they have reached neighboring states. Scientists are concerned that one day they might arrive in Yellowstone.

Zebra mussels are an invasive species that first appeared in the Great Lakes in the 1980’s. Ever since then they have been spreading around the country. They spread easily partly because each female can lay millions of eggs. Young mussels float along the water currents. Eventually they attach themselves to hard surfaces like rocks and the bottom of boats. Colonies can become very dense with as many as 10,000 mussels per square foot. Zebra mussels also cling to native mussels and other shelled animals. These animals die because they can’t feed. Zebra mussels disrupt ecosystems by eating microscopic animals and plankton. This reduces the food available for the native invertebrates and small fish. They also disrupt ecosystem services by clogging water pipes to businesses and power plants. They damage boats, docks, buoys, and other structures.
Environmental Problem 4

Chesapeake Bay is the largest estuary in the country. Over 100,000 rivers and streams from six states, including New York, drain into the bay. Over 16 million people live close to these streams and rivers. It used to be the world’s largest oyster-producing region. However, this century the oyster harvest is only about 1% of what it was 100 years ago. The reasons for this large decline include destruction of habitat, overharvesting, disease, and reduction in water quality. The decrease in oysters has had a major effect on the environment and the local economy. Without large numbers of oysters, the water in the bay is not filtered well. The water quality is made worse by runoff into the streams and rivers that feed into the bay. The runoff is rich in nutrients. This has increased algae growth in the bay. When the algae die, they sink to the bottom of the bay where bacteria decompose them. The presence of large numbers of bacteria reduces the oxygen content of the water, causing dead zones. Very few organisms can survive in these zones. Some of the organisms that are mobile, such as crabs and fish, can move out of the dead zone. Other organisms that cannot move as freely, such as oysters, are more likely to die in dead zones.

An oyster catch in Chesapeake Bay.
Coral reefs make up a tiny fraction of the ocean floor but are home to about one million species. It is estimated that about one quarter of all marine organisms live in or near coral reefs. Reefs are important for more than their biodiversity. They help protect coasts from tropical storms, reducing erosion. They are breeding grounds and nurseries for many marine organisms. They also contribute billions of dollars to local economies through ecosystem services such as fishing, tourism, and recreation. However, coral reefs are fragile. Over the past 50 years more than a quarter of the world’s reefs have been destroyed. The threats to coral reefs are many and varied. In this final activity you will look at some of these threats as you design and evaluate potential solutions.
Guiding Question
How can the negative impact of humans on coral reefs be reduced?

Process & Procedure
1. Use the Read, Think, and Take Note strategy as you complete the reading on coral reefs.

Read, Think, and Take Note: Guidelines
As you read, stop at least three times to write one of the following:
- Explain a thought or reaction to something you read.
- Note something in the reading that is confusing or unfamiliar.
- Identify a word that you do not know.
- Describe a connection to something you learned or read previously.
- Make a statement about the reading.
- Ask a question about the reading.

2. With your group, select one of the threats affecting coral reefs.

3. Write a paragraph that summarizes the threat and why it is important to develop a solution.

4. In your group, design a method to stop or reduce the threats to coral reefs. In your design, make sure to include the following:
   - The environmental, economic, and social aspects of your proposed solution.
   - The criteria and constraints that apply to your solution.
   - The evidence that you would need to see in order for you to feel that your solution had worked.

5. Follow your teacher’s directions to present your solution to the class.

6. Listen to the presentations of other groups and evaluate each of the proposed solutions against the chosen criteria and constraints.
Analysis

1. Some of the causes of threats to the health of coral reefs are local and some are global. How does the challenge of designing and applying a solution differ when the cause is a worldwide problem, such as climate change?

Threats to Coral Reefs

Coral reefs are made up of millions of tiny invertebrate animals called polyps. The polyps rely on algae for their survival. The algae live inside the tissues of the polyps and are producers, capturing the energy of the sun. Most polyps use chemicals in the sea-water to make a hard structure around them in which they live. It is these hard cases that make up coral reefs. Healthy coral reefs are full of color and life with many organisms making their homes in or near the reef.

Coral reefs are also easily damaged and are under threat in many parts of the world. On a global level, climate change is causing some parts of the ocean to be warmer. It is also causing some parts of the ocean to become more acidic. These increases in temperature and acidity can damage or even kill the coral reefs. These global threats can be very difficult to address, because they require so many people all over the world to work together.
On a local level there are also a number of threats to coral reefs. These threats can often be addressed by the people living in the communities near the coral reefs. The large number and types of fish that live in coral reefs makes them places that appeal to fishermen. However, overfishing can cause the number of fish to go down. It can also cause the average size of the fish that are caught to decrease, as fish are caught at a younger age. In order to catch enough fish to feed their families and to sell, some people turn to destructive fishing techniques. One such technique is dynamite fishing, where explosives are thrown into the water. Both the explosion and the shockwaves kill or stun the fish in the blast area. This allows the fishermen to collect a large number of fish in a short period of time. The explosion also causes great damage to the coral in the reef. In the end this reduces the amount of coral and the number of fish and other organisms in the area. Even when non-destructive fishing techniques are used, reefs can be harmed. If one or more species is overfished, the food web can become unbalanced. You read about one example of this in the last activity, with the crown-of-thorns sea star.

The beauty of coral reefs makes them an attractive destination for many people. The presence of tourists is important to the local economy as it benefits businesses, such as tour companies, hotels, and restaurants. Unfortunately, tourism can also cause problems.
for the reef ecosystem. When swimmers and divers stand on or even touch a reef, the coral can be damaged. This is even more of a problem when boats drop their anchors onto the reef. Boats can also cause pollution with the gasoline and oil that they use. Development of the coast causes an indirect threat to reefs that are nearby. As roads, hotels, and other buildings are constructed, debris and sediment can wash into the ocean and smother the reef. Sediment can also reduce the clarity of the water, which affects the ability of the algae to capture the energy of the sun. Nutrients from substances such as fertilizer can be washed from coastal developments into the ocean. This can cause weed-like algae to grow quickly and overgrow a reef. An increase in the nutrients in the water also allows more of the young crown-of-thorns sea stars to survive and become adults.
Control Methods

A) Chemical control
A pesticide would be sprayed on the plants and the soil. The pesticide is very effective at killing any beetles that it touches. It is also poisonous to many other insects and some small animals. The effectiveness of the pesticide decreases rapidly over time. The insecticide would have to be reapplied frequently over a two-month period.

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
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<tbody>
<tr>
<td></td>
<td></td>
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</tbody>
</table>

B) Relocate the farm
Holly, her parents, and her two younger brothers would move to a new location several hundred miles away. This would involve selling the farm and leaving her school and friends behind. It is uncertain if the farm could be sold for enough money to buy another farm in the new location. If not, then Holly’s parents would have to find different jobs.

<table>
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</table>
C) Biological control

Toads will be used to control the beetles. The toads eat many types of small organisms, such as frogs, lizards, snakes, mice, snails, and insects. They have been used successfully to control insect pests in several other countries. The toads are not native to the area. Thirty toads will be brought to the farm and released in the fields.

D) Physical removal

All of the fields would be burned. This would kill all of the crops but would also kill the insects, including the grubs that live in the soil. The fields would be left bare for one year. Workers would be hired to monitor the fields and trap and remove any of the beetles that were found there. After one year, the crops would be replanted. Workers would continue to monitor the fields for the beetles until the crops could be harvested later in the year.
Control Methods

A) Chemical control
A pesticide would be sprayed on the plants and the soil. The pesticide is very effective at killing any beetles that it touches. It is also poisonous to many other insects and some small animals. The effectiveness of the pesticide decreases rapidly over time. The insecticide would have to be reapplied frequently over a two-month period.

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kills insects that it touches.</td>
<td>Poisons other insects and small animals.</td>
</tr>
<tr>
<td>It is easy to use.</td>
<td>Doesn’t last long and has to be reapplied frequently.</td>
</tr>
<tr>
<td></td>
<td>Could kill the crops.</td>
</tr>
<tr>
<td></td>
<td>Could make people sick.</td>
</tr>
</tbody>
</table>

B) Relocate the farm
Holly, her parents, and her two younger brothers would move to a new location several hundred miles away. This would involve selling the farm and leaving her school and friends behind. It is uncertain if the farm could be sold for enough money to buy another farm in the new location. If not, then Holly’s parents would have to find different jobs.

<table>
<thead>
<tr>
<th>Advantages</th>
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</tr>
</thead>
<tbody>
<tr>
<td>They would be away from the insects.</td>
<td>Move away from school and friends.</td>
</tr>
<tr>
<td>Will get some money by selling the farm.</td>
<td>Might not have enough money to buy a new farm.</td>
</tr>
<tr>
<td></td>
<td>Parents may have to get new jobs.</td>
</tr>
<tr>
<td></td>
<td>Will have to make new friends.</td>
</tr>
</tbody>
</table>
C) Biological control

Toads will be used to control the beetles. The toads eat many types of small organisms, such as frogs, lizards, snakes, mice, snails, and insects. They have been used successfully to control insect pests in several other countries. The toads are not native to the area. Thirty toads will be brought to the farm and released in the fields.

<table>
<thead>
<tr>
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<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>The toads will eat the insects.</td>
<td>They are not native to the area.</td>
</tr>
<tr>
<td>This won’t hurt the crops or the environment.</td>
<td>Something may kill the toads.</td>
</tr>
<tr>
<td>The toads can protect the crops from other small animals that could attack the crops.</td>
<td>The toads might run away.</td>
</tr>
<tr>
<td>It has worked in other countries.</td>
<td>The toads might not be able to adapt.</td>
</tr>
<tr>
<td></td>
<td>The toads each more than insects.</td>
</tr>
</tbody>
</table>

D) Physical removal

All of the fields would be burned. This would kill all of the crops but would also kill the insects, including the grubs that live in the soil. The fields would be left bare for one year. Workers would be hired to monitor the fields and trap and remove any of the beetles that were found there. After one year, the crops would be replanted. Workers would continue to monitor the fields for the beetles until the crops could be harvested later in the year.

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>It would kill the insects.</td>
<td>It would kill the crops and maybe some animals.</td>
</tr>
<tr>
<td>The crops would be replanted without any insects.</td>
<td>It takes a long time</td>
</tr>
<tr>
<td></td>
<td>Holly’s family would not have crops (to eat and sell) for at least one year.</td>
</tr>
<tr>
<td></td>
<td>Sounds like it would cost a lot of money.</td>
</tr>
<tr>
<td></td>
<td>The fire could get out of control.</td>
</tr>
<tr>
<td></td>
<td>The smoke from the fire causes pollution.</td>
</tr>
</tbody>
</table>
EVENT CARDS
ROUND 1

Activity 5.2
**Action**

There is a proposal to build a much-needed housing development. As a group, you must decide whether to approve the proposal and, if so, where it should be built.

**Consequence**

If you decide to allow the new housing development:

<table>
<thead>
<tr>
<th>Who is affected</th>
<th>Environmental Points change</th>
<th>Money Points change</th>
<th>Happiness Points change</th>
</tr>
</thead>
<tbody>
<tr>
<td>The manager of the area where the development is built</td>
<td>Subtract two points</td>
<td>Add two points</td>
<td>Add two points</td>
</tr>
<tr>
<td>The manager of the Gulf area</td>
<td>Subtract two points</td>
<td>Add two points</td>
<td>Add two points</td>
</tr>
<tr>
<td>All others</td>
<td>Subtract one point</td>
<td>Add one point</td>
<td>Add one point</td>
</tr>
</tbody>
</table>

If you decide not to allow the new housing development:

<table>
<thead>
<tr>
<th>Who is affected</th>
<th>Environmental Points change</th>
<th>Money Points change</th>
<th>Happiness Points change</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>Add one point</td>
<td>Subtract one point</td>
<td>Subtract one point</td>
</tr>
</tbody>
</table>

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**Action**

There is a proposal to establish a large farm near the river. As a group, you must decide whether to approve the proposal.

**Consequence**

If you decide to allow the new farm:

<table>
<thead>
<tr>
<th>Who is affected</th>
<th>Environmental Points change</th>
<th>Money Points change</th>
<th>Happiness Points change</th>
</tr>
</thead>
<tbody>
<tr>
<td>The manager of the River area</td>
<td>Subtract two points</td>
<td>Add two points</td>
<td>Add two points</td>
</tr>
<tr>
<td>The manager of the Gulf area</td>
<td>Subtract two points</td>
<td>Add two points</td>
<td>Add two points</td>
</tr>
<tr>
<td>All others</td>
<td>Subtract one point</td>
<td>Add one point</td>
<td>Add one point</td>
</tr>
</tbody>
</table>

If you decide not to allow the farm:

<table>
<thead>
<tr>
<th>Who is affected</th>
<th>Environmental Points change</th>
<th>Money Points change</th>
<th>Happiness Points change</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>Add one point</td>
<td>Subtract one point</td>
<td>Subtract one point</td>
</tr>
</tbody>
</table>

---

**Consequence**

If you decide to allow the new housing development:

<table>
<thead>
<tr>
<th>Who is affected</th>
<th>Environmental Points change</th>
<th>Money Points change</th>
<th>Happiness Points change</th>
</tr>
</thead>
<tbody>
<tr>
<td>The manager of the area where the development is built</td>
<td>Subtract two points</td>
<td>Add two points</td>
<td>Add two points</td>
</tr>
<tr>
<td>All others</td>
<td>Subtract one point</td>
<td>Add one point</td>
<td>Add one point</td>
</tr>
</tbody>
</table>

If you decide not to allow the new housing development:

<table>
<thead>
<tr>
<th>Who is affected</th>
<th>Environmental Points change</th>
<th>Money Points change</th>
<th>Happiness Points change</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>Add one point</td>
<td>Subtract one point</td>
<td>Subtract two points</td>
</tr>
</tbody>
</table>
EVENT CARDS

ROUND 1

Activity 5.2
**Action**

There is a proposal to build a road that by-passes the town and reduces traffic congestion. The road will begin near the river before passing through the gulf near to the city and on up through the forest. As a group, you must decide whether to approve the proposal.

**Consequence**

If you decide to allow the new road:

<table>
<thead>
<tr>
<th>Who is affected</th>
<th>Environmental Points change</th>
<th>Money Points change</th>
<th>Happiness Points change</th>
</tr>
</thead>
<tbody>
<tr>
<td>The manager of the Lake area</td>
<td>No change</td>
<td>Add one point</td>
<td>Add two points</td>
</tr>
<tr>
<td>All others</td>
<td>Subtract two points</td>
<td>Add one point</td>
<td>Add two points</td>
</tr>
</tbody>
</table>

If you decide not to allow the new road:

<table>
<thead>
<tr>
<th>Who is affected</th>
<th>Environmental Points change</th>
<th>Money Points change</th>
<th>Happiness Points change</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>Add one point</td>
<td>Subtract one point</td>
<td>Subtract one point</td>
</tr>
</tbody>
</table>

---

**Action**

There is a proposal to build a small industrial complex. As a group, you must decide whether to approve the proposal and, if so, where it should be built.

**Consequence**

If you decide to allow the new industrial complex:

<table>
<thead>
<tr>
<th>Who is affected</th>
<th>Environmental Points change</th>
<th>Money Points change</th>
<th>Happiness Points change</th>
</tr>
</thead>
<tbody>
<tr>
<td>The manager of the area where the development is built</td>
<td>Subtract two points</td>
<td>Add two points</td>
<td>Add one point</td>
</tr>
<tr>
<td>All others</td>
<td>Subtract one point</td>
<td>Add one point</td>
<td>Add one point</td>
</tr>
</tbody>
</table>

If you decide not to allow the new industrial complex:

<table>
<thead>
<tr>
<th>Who is affected</th>
<th>Environmental Points change</th>
<th>Money Points change</th>
<th>Happiness Points change</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>Add one point</td>
<td>Subtract two points</td>
<td>Subtract one point</td>
</tr>
</tbody>
</table>
EVENT CARDS
ROUND 1

Activity 5.2
There is a proposal to temporarily suspend all fishing in the lake as fish populations reach historically low levels. As a group, you must decide whether to approve the proposal.

### Action

If you decide to suspend fishing:

<table>
<thead>
<tr>
<th>Who is affected</th>
<th>Environmental Points change</th>
<th>Money Points change</th>
<th>Happiness Points change</th>
</tr>
</thead>
<tbody>
<tr>
<td>The manager of the Lake area</td>
<td>Add three points</td>
<td>Subtract two points</td>
<td>Subtract two points</td>
</tr>
<tr>
<td>All others</td>
<td>Add two points</td>
<td>Subtract one point</td>
<td>Subtract one point</td>
</tr>
</tbody>
</table>

If you decide to allow fishing:

<table>
<thead>
<tr>
<th>Who is affected</th>
<th>Environmental Points change</th>
<th>Money Points change</th>
<th>Happiness Points change</th>
</tr>
</thead>
<tbody>
<tr>
<td>The manager of the Lake area</td>
<td>Subtract two points</td>
<td>Add two points</td>
<td>Add one point</td>
</tr>
<tr>
<td>The manager of the River area</td>
<td>Subtract two points</td>
<td>Add two points</td>
<td>Add one point</td>
</tr>
<tr>
<td>All others</td>
<td>Subtract one point</td>
<td>Add one point</td>
<td>Add one point</td>
</tr>
</tbody>
</table>
### Action

There is a proposal to introduce a new species of fish into the lake. This species is much larger than the existing species of fish. Those who support this proposal think that it will attract people who enjoy fishing, therefore increasing area tourism. Those who oppose the introduction are concerned about how it will affect the ecosystem, especially the other fish in the lake. As a group, you must decide whether to support the proposal.

### Consequence

#### If you decide to allow the introduction of the fish:

<table>
<thead>
<tr>
<th>Who is affected</th>
<th>Environmental Points change</th>
<th>Money Points change</th>
<th>Happiness Points change</th>
</tr>
</thead>
<tbody>
<tr>
<td>The manager of the Lake area</td>
<td>Subtract two points</td>
<td>Add one point</td>
<td>Add one point</td>
</tr>
<tr>
<td>The manager of the River area</td>
<td>Subtract two points</td>
<td>Add one point</td>
<td>Add one point</td>
</tr>
<tr>
<td>The manager of the Gulf area</td>
<td>Subtract two points</td>
<td>Add one point</td>
<td>Add one point</td>
</tr>
<tr>
<td>The manager of the Forest area</td>
<td>No change</td>
<td>Add one point</td>
<td>Add one point</td>
</tr>
</tbody>
</table>

#### If you decide not to introduce the fish:

<table>
<thead>
<tr>
<th>Who is affected</th>
<th>Environmental Points change</th>
<th>Money Points change</th>
<th>Happiness Points change</th>
</tr>
</thead>
<tbody>
<tr>
<td>All managers</td>
<td>Add one point</td>
<td>Subtract two points</td>
<td>Subtract one point</td>
</tr>
</tbody>
</table>

### Action

There is a proposal to build a dam where the lake meets the river. The dam would generate additional electricity for the region, which is important in supporting the growing population. However, the dam would reduce the flow of water into the river. It would also allow the flow of water to be controlled. Your community’s support will be crucial in order for the dam to be built. As a group, you must decide whether to support the proposal.

### Consequence

#### If you decide to build the dam:

<table>
<thead>
<tr>
<th>Who is affected</th>
<th>Environmental Points change</th>
<th>Money Points change</th>
<th>Happiness Points change</th>
</tr>
</thead>
<tbody>
<tr>
<td>The manager of the Lake area</td>
<td>Subtract two points</td>
<td>Add one point</td>
<td>Add one point</td>
</tr>
<tr>
<td>The manager of the River area</td>
<td>Subtract two points</td>
<td>Add one point</td>
<td>Add one point</td>
</tr>
<tr>
<td>The manager of the Gulf area</td>
<td>Subtract two points</td>
<td>Add one point</td>
<td>Add one point</td>
</tr>
<tr>
<td>The manager of the Forest area</td>
<td>No change</td>
<td>Add one point</td>
<td>Add one point</td>
</tr>
</tbody>
</table>

#### If you decide not to build the dam:

<table>
<thead>
<tr>
<th>Who is affected</th>
<th>Environmental Points change</th>
<th>Money Points change</th>
<th>Happiness Points change</th>
</tr>
</thead>
<tbody>
<tr>
<td>All managers</td>
<td>Add one point</td>
<td>Subtract two points</td>
<td>Subtract one point</td>
</tr>
</tbody>
</table>
**Action**

The increasing population of the region means that several new schools must be built. The Forest and Gulf area will each have a new elementary school, while the River area will be the site of a large middle and high school campus.

**Consequence**

If you decide to build the schools:

<table>
<thead>
<tr>
<th>Who is affected</th>
<th>Environmental Points change</th>
<th>Money Points change</th>
<th>Happiness Points change</th>
</tr>
</thead>
<tbody>
<tr>
<td>The manager of the River area</td>
<td>Subtract two points</td>
<td>No change</td>
<td>Add two points</td>
</tr>
<tr>
<td>The managers of the Forest and Gulf areas</td>
<td>Subtract one point</td>
<td>No change</td>
<td>Add two points</td>
</tr>
<tr>
<td>The manager of the Lake area</td>
<td>No change</td>
<td>No change</td>
<td>Add two points</td>
</tr>
</tbody>
</table>

If you decide not to build the schools:

<table>
<thead>
<tr>
<th>Who is affected</th>
<th>Environmental Points change</th>
<th>Money Points change</th>
<th>Happiness Points change</th>
</tr>
</thead>
<tbody>
<tr>
<td>The manager of the River area</td>
<td>Add one point</td>
<td>No change</td>
<td>Subtract two points</td>
</tr>
<tr>
<td>The managers of the Forest and Gulf areas</td>
<td>Add one point</td>
<td>No change</td>
<td>Subtract two points</td>
</tr>
<tr>
<td>The manager of the Lake area</td>
<td>No change</td>
<td>No change</td>
<td>Subtract two points</td>
</tr>
</tbody>
</table>

If you decide not to support the proposal and the resort is not built:

<table>
<thead>
<tr>
<th>Who is affected</th>
<th>Environmental Points change</th>
<th>Money Points change</th>
<th>Happiness Points change</th>
</tr>
</thead>
<tbody>
<tr>
<td>The manager of the Gulf area</td>
<td>Subtract two points</td>
<td>Add two points</td>
<td>Add one point</td>
</tr>
<tr>
<td>All others</td>
<td>No change</td>
<td>Add one point</td>
<td>Add one point</td>
</tr>
</tbody>
</table>

If your group cannot agree whether the resort should be built:

<table>
<thead>
<tr>
<th>Who is affected</th>
<th>Environmental Points change</th>
<th>Money Points change</th>
<th>Happiness Points change</th>
</tr>
</thead>
<tbody>
<tr>
<td>All managers</td>
<td>No change</td>
<td>Subtract one point</td>
<td>Subtract two points</td>
</tr>
</tbody>
</table>

There is a proposal to build a large resort in the Gulf area that will boost tourism.
Action
There is a prolonged period of heavy rain which causes flooding.

Consequence
If you built the dam in Round 2:

<table>
<thead>
<tr>
<th>Who is affected</th>
<th>Environmental Points change</th>
<th>Money Points change</th>
<th>Happiness Points change</th>
</tr>
</thead>
<tbody>
<tr>
<td>The manager of the Lake area</td>
<td>Subtract one point</td>
<td>Subtract one point</td>
<td>Subtract one point</td>
</tr>
<tr>
<td>The manager of the River area</td>
<td>Subtract one point</td>
<td>Subtract one point</td>
<td>Subtract one point</td>
</tr>
<tr>
<td>The manager of the Gulf area</td>
<td>Subtract one point</td>
<td>Subtract one point</td>
<td>Subtract one point</td>
</tr>
<tr>
<td>The manager of the Forest area</td>
<td>No change</td>
<td>Subtract one point</td>
<td>Subtract one point</td>
</tr>
</tbody>
</table>

If you did not build the dam in Round 2:

<table>
<thead>
<tr>
<th>Who is affected</th>
<th>Environmental Points change</th>
<th>Money Points change</th>
<th>Happiness Points change</th>
</tr>
</thead>
<tbody>
<tr>
<td>The manager of the Lake area</td>
<td>Subtract one point</td>
<td>Subtract two points</td>
<td>Subtract two points</td>
</tr>
<tr>
<td>The manager of the River area</td>
<td>Subtract two points</td>
<td>Subtract two points</td>
<td>Subtract two points</td>
</tr>
<tr>
<td>The manager of the Gulf area</td>
<td>Subtract two points</td>
<td>Subtract two points</td>
<td>Subtract two points</td>
</tr>
<tr>
<td>The manager of the Forest area</td>
<td>No change</td>
<td>Subtract one point</td>
<td>Subtract one point</td>
</tr>
</tbody>
</table>

Action
The increasing population of the region has meant that there is more traffic on the roads. This can cause more congestion and pollution in communities close to the road.

Consequence
If you built a by-pass road in Round 1:

<table>
<thead>
<tr>
<th>Who is affected</th>
<th>Environmental Points change</th>
<th>Money Points change</th>
<th>Happiness Points change</th>
</tr>
</thead>
<tbody>
<tr>
<td>The manager of the Lake area</td>
<td>No change</td>
<td>No change</td>
<td>No change</td>
</tr>
<tr>
<td>All others</td>
<td>Subtract two points</td>
<td>No change</td>
<td>No change</td>
</tr>
</tbody>
</table>

If you did not build a by-pass road in Round 1:

<table>
<thead>
<tr>
<th>Who is affected</th>
<th>Environmental Points change</th>
<th>Money Points change</th>
<th>Happiness Points change</th>
</tr>
</thead>
<tbody>
<tr>
<td>The manager of the Lake area</td>
<td>Subtract one point</td>
<td>No change</td>
<td>Subtract one point</td>
</tr>
<tr>
<td>All others</td>
<td>Subtract two points</td>
<td>No change</td>
<td>Subtract one point</td>
</tr>
</tbody>
</table>
Action
Slowly but surely, various nonnative species have entered the region. The effect that these species have on your area depends partly on how healthy your environment is.

Consequence

<table>
<thead>
<tr>
<th>Who is affected</th>
<th>Environmental Points change</th>
<th>Money Points change</th>
<th>Happiness Points change</th>
</tr>
</thead>
<tbody>
<tr>
<td>If you have 10 or more environmental points</td>
<td>No change</td>
<td>No change</td>
<td>No change</td>
</tr>
<tr>
<td>If you have between 6 and 9 environmental points</td>
<td>Subtract one point</td>
<td>Subtract one point</td>
<td>Subtract one point</td>
</tr>
<tr>
<td>If you have 5 or less environmental points</td>
<td>Subtract two points</td>
<td>Subtract two points</td>
<td>Subtract two points</td>
</tr>
</tbody>
</table>

Action
A private foundation has offered to provide the funds needed to create a conservation area in the most economically disadvantaged area in the region.

Consequence

<table>
<thead>
<tr>
<th>Who is affected</th>
<th>Environmental Points change</th>
<th>Money Points change</th>
<th>Happiness Points change</th>
</tr>
</thead>
<tbody>
<tr>
<td>If you have the lowest number of money points*</td>
<td>Add two points</td>
<td>Add one point</td>
<td>Add one point</td>
</tr>
<tr>
<td>All others</td>
<td>No change</td>
<td>No change</td>
<td>No change</td>
</tr>
</tbody>
</table>

*If two or more members of your group are tied for the lowest number of money points, you must agree as a group where the conservation area will be located.
EVENT CARDS
ROUND 3

Activity 5.2
Economic conditions in the state have deteriorated quite badly. Many families are relocating to find work. The effect that these economic problems have on your area depends on the total of your money and happiness points.

**Consequence**

<table>
<thead>
<tr>
<th>Who is affected</th>
<th>Environmental Points change</th>
<th>Money Points change</th>
<th>Happiness Points change</th>
</tr>
</thead>
<tbody>
<tr>
<td>If you have a total of 16 or more money and happiness points</td>
<td>No change</td>
<td>No change</td>
<td>Subtract one point</td>
</tr>
<tr>
<td>If you have a total of 10 to 15 money and happiness points</td>
<td>No change</td>
<td>Subtract two points</td>
<td>Subtract two points</td>
</tr>
<tr>
<td>If you have a total of 9 or less money and happiness points</td>
<td>No change</td>
<td>Subtract three points</td>
<td>Subtract three points</td>
</tr>
</tbody>
</table>
## Score Sheet

**Area managed (circle one):**  
- Lake  
- River  
- Forest  
- Gulf

<table>
<thead>
<tr>
<th>Round</th>
<th>Turn</th>
<th>Event</th>
<th>Environmental points</th>
<th>Money points</th>
<th>Happiness points</th>
<th>Total points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start</td>
<td>0</td>
<td></td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>30</td>
</tr>
</tbody>
</table>

**Round 1**

1
2
3
4

**Round 2**

1
2
3
4

**Round 3**

1
2
3
4

Carry the score on to the next round

Carry the score on to the next round
### Score Sheet

**Area managed (circle one):** Lake

<table>
<thead>
<tr>
<th>Round</th>
<th>Turn</th>
<th>Event</th>
<th>Environmental points</th>
<th>Money points</th>
<th>Happiness points</th>
<th>Total points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Start</strong></td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>30</td>
</tr>
<tr>
<td>Round 1</td>
<td>1</td>
<td><strong>Add a farm – Yes</strong></td>
<td>9</td>
<td>11</td>
<td>11</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td><strong>Add an industrial complex – Yes</strong></td>
<td>8</td>
<td>12</td>
<td>12</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td><strong>Hunting - No</strong></td>
<td>10</td>
<td>11</td>
<td>11</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td><strong>Build a housing development - Yes</strong></td>
<td>9</td>
<td>12</td>
<td>12</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Carry the score on to the next round</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Round 2</td>
<td>1</td>
<td><strong>Build a dam - No</strong></td>
<td>10</td>
<td>10</td>
<td>11</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td><strong>Add a new type of fish - No</strong></td>
<td>12</td>
<td>8</td>
<td>9</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td><strong>Build a bypass - Yes</strong></td>
<td>11</td>
<td>8</td>
<td>8</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td><strong>Build a resort - Yes</strong></td>
<td>11</td>
<td>9</td>
<td>9</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Carry the score on to the next round</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Round 3</td>
<td>1</td>
<td><strong>Private foundation</strong></td>
<td>13</td>
<td>10</td>
<td>10</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td><strong>Non-native species</strong></td>
<td>13</td>
<td>10</td>
<td>10</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td><strong>Economic conditions</strong></td>
<td>13</td>
<td>10</td>
<td>9</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td><strong>Flooding</strong></td>
<td>12</td>
<td>8</td>
<td>7</td>
<td>27</td>
</tr>
</tbody>
</table>
**Constraint:**
The family does not have to move away from the farm.

**Criteria:**
1. Has the least negative environmental impact
2. Does not take a long time
Constraint:
There should be no use of chemicals.

Criteria:
1. Has the least negative social impact
2. Keeps as much of the crops as possible

Constraint:
There should be no use of chemicals.

Criteria:
1. Has the least negative social impact
2. Keeps as much of the crops as possible
## Analyzing the Insect Solutions

<table>
<thead>
<tr>
<th>Solution to Insect Problem</th>
<th>Economic Impact</th>
<th>Social Impact</th>
<th>Environmental Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Chemical Control</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B. Relocate the Farm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. Biological Control</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D. Physical Removal</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Analyzing the Insect Solutions

<table>
<thead>
<tr>
<th>Solution to Insect Problem</th>
<th>Economic Impact</th>
<th>Social Impact</th>
<th>Environmental Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Chemical Control</td>
<td>Might be expensive because it has to be reapplied frequently over a 2 month period.</td>
<td>Might make people sick.</td>
<td>Kills other insects and small animals. Might harm the crops.</td>
</tr>
<tr>
<td>B. Relocate the Farm</td>
<td>Might lose money when selling the farm, moving, and buying a new home.</td>
<td>Move away from friends and school. Parents may have to find new jobs if they can’t find another farm.</td>
<td>The insects will still be there. A new farm may replace a natural area.</td>
</tr>
<tr>
<td>C. Biological Control</td>
<td>Might be expensive if the toads become invasive and spread.</td>
<td>Small pets can be harmed by the toads.</td>
<td>The toad will affect the food web of the ecosystem. The toad could become an invasive species.</td>
</tr>
<tr>
<td>D. Physical Removal</td>
<td>Expensive because there would be no crops for a year and many workers would have to be hired.</td>
<td>Might have to find new jobs until the crops grew again.</td>
<td>Pollution from the smoke when the crops are burned. It will kill some native organisms.</td>
</tr>
</tbody>
</table>
Designing a Solution

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Describe the problem.</td>
<td></td>
</tr>
<tr>
<td>2. Describe the needs that the solution is to address.</td>
<td></td>
</tr>
<tr>
<td>3. Identify the constraints that the solution must meet.</td>
<td>4. Identify the criteria that apply to the solution.</td>
</tr>
</tbody>
</table>
Designing a Solution
Continued

5. Which of the proposed solutions, or combinations of solutions, best meets the criteria and constraints? Make sure to provide your reasoning.

6. How could the solution be improved? (You may adjust the criteria and the solutions)
**Designing a Solution**

<table>
<thead>
<tr>
<th>1. Describe the problem.</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Insects are damaging the sugar cane crop.</em></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2. Describe the needs that the solution is to address.</th>
</tr>
</thead>
</table>
| *The insects that are damaging the crops should be stopped from doing any more damage.*  
*Note: Students may add more needs, such as the family needs to earn more money to make up for the lost crops, etc.* |

<table>
<thead>
<tr>
<th>3. Identify the constraints that the solution must meet.</th>
<th>4. Identify the criteria that apply to the solution.</th>
</tr>
</thead>
</table>
| *Student responses will vary. An example is given below.*  
*All of the insects must be killed.* | *Student responses will vary. An example is given below.*  
*Social: The solution should be quick.*  
*Environmental and economic: The solution should preserve as much of the crop as possible.* |
5. Which of the proposed solutions, or combinations of solutions, best meets the criteria and constraints? Make sure to provide your reasoning.

We believe that chemical control is the solution that best meets our criteria and constraint.

The chemicals should kill all of the insects, which means it meets our constraint.

It does not require removing or burning any of the sugar cane. Therefore it meets one of the criteria. It also seems quicker than the other solutions, which means it is best at meeting the other criterion.

6. How could the solution be improved? (You may adjust the criteria and the solutions)

We recommend using chemical control but we would also employ people to check the fields so that we would know when the insects were all gone. We would then know when to stop spraying the chemical on the crops. We could also employ the people to check the fields every now and again, to make sure that the insects didn’t come back. It would cost extra money to employ the people but we might save money by stopping using the chemical sooner. We would also continue to have crops to sell.
Possible Solutions

Environmental Problem 1 – Potential Solutions

A. Employ divers to find the crown-of-thorns starfish and inject them with a fluid that kills them. ($150,000)
B. Create a protected area around the reef where no fishing is allowed. ($200,000)
C. Ask people to monitor and report the numbers of the starfish. ($200,000)
D. Introduce a new predator that eats the eggs and the young starfish. ($150,000)
E. Employ fishermen to remove the crown-of-thorn starfish and move them to other areas. ($150,000)

<table>
<thead>
<tr>
<th>Notes:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>
Possible Solutions

Environmental Problem 2 – Potential Solutions

A. Enforce policing of the protected area and apply heavy fines for misuse. ($150,000)

B. Move the people in the village to a new area far away from the lake. ($200,000)

C. Offer more educational opportunities to teach the villagers new skills. ($100,000)

D. Help the villagers to change their crops to ones that need less space to grow. ($200,000)

E. Employ the villagers to clean the sediment from the lake. ($150,000)

Notes:
Possible Solutions

Environmental Problem 3 – Potential Solutions

A. Increase the frequency of monitoring the lake and nearby rivers for the presence of zebra mussels. ($200,000)

B. Ban all boats from lakes and rivers within 25 miles of Yellowstone National Park. ($100,000)

C. Require all boat owners to inspect their boats and certify that they are clear of zebra mussels before entering the park. ($100,000)

D. Introduce a zebra mussel predator into Yellowstone Lake so that if the mussel arrives, it will be eaten. ($150,000)

E. Apply a low-dosage of chemicals to the lake to prevent zebra mussel colonies from becoming established. ($150,000)

F. Educate the people who live in and around the park to recognize zebra mussels and how to prevent their spread. ($100,000)

G. Have mandatory inspection points on all roads that lead to the park. All boats would be sprayed with chemicals at the inspection points. ($100,000)

Notes:
Possible Solutions

Environmental Problem 4 – Potential Solutions

A. Ban the harvesting of oysters until the oyster population has recovered to what it was 100 years ago. ($200,000)

B. Introduce a larger, fast-growing oyster from Asia that can filter the waters and can also be harvested and sold. ($200,000)

C. Ban the use of substances such as fertilizer in communities close to the rivers and streams that drain into the bay. ($150,000)

D. Install filtering systems that reduce the nutrients in runoff at the mouths of the rivers and streams that drain into the bay. ($350,000)

E. Retrain the people who rely on the oyster fishery to catch and sell other organisms, such as crabs, instead. ($150,000)

Notes:
1. Describe the problem.

*Overfishing of predators of crown-of-thorns starfish is causing damage to the coral reef, especially to slow growing coral.*

2. Describe the needs that the solution is to address.

*Protect the reef.*  
*Maintain the biodiversity of the reef.*  
*(Students may also suggest - Protect ecosystem services.)*

3. Identify the constraints that the solution must meet.

*Total budget cannot be more than $500,000.*

4. Identify the criteria that apply to the solution.

1. *Remove as many crown-of-thorns starfish as possible.*  
   *(Environmental and economic)*

2. *Maintain ecosystem services as much as possible.*  
   *(Economic and social)*

3. *Maintain the biodiversity of the coral reef.*  
   *(Environmental)*
5. Which of the proposed solutions, or combinations of solutions, best meets the criteria and constraints? Make sure to provide your reasoning.

Solutions A, D, and E would probably remove the most crown-of-thorns starfish, which means they are a good match for criterion 1. However, solution D would affect the biodiversity of the coral reef by introducing a new species therefore it does not work well with criterion 3.

Solution B affects ecosystem services in a negative way so it does not meet criterion 2 well.

I would use a combination of solutions C and E. This would remove the crown-of-thorns starfish, and provide a way of monitoring their numbers. It also provides more jobs for people in the area. The total cost would be $350,000 which means that it meets the constraint.

6. How could the solution be improved? (You may adjust the criteria and the solutions)

Solutions C and E reduce the number of crown-of-thorns starfish but they don’t solve the problem of overfishing of its predators. I would use the remaining $150,000 to monitor fishing in the area and educate people not to catch the predators of the crown-of-thorns starfish.
### Designing a Solution

#### Activity 5.4

**Environmental Problem 2**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Describe the problem.</strong></td>
<td>The forest is a protected area but is being used by local people. Sometimes the trees are cut down by local people. This is negatively affecting the forest and the lake.</td>
</tr>
<tr>
<td><strong>2. Describe the needs that the solution is to address.</strong></td>
<td>Protect the forest. Protect the quality of the water in the lake. Protect the biodiversity in the forest and the lake. (Students may also suggest – Help the local people with food and jobs.)</td>
</tr>
<tr>
<td><strong>3. Identify the constraints that the solution must meet.</strong></td>
<td>Total budget cannot be more than $500,000.</td>
</tr>
</tbody>
</table>
| **4. Identify the criteria that apply to the solution.** | 1. The biodiversity of the forest and the lake should be maintained. (Environmental)  
2. The quality of the lake water should be as high as possible. (Environmental and social)  
3. The food supply for the villagers should be improved. (Social and economic)  
4. Protect as much of the forest as possible. (Environmental) |
5. Which of the proposed solutions, or combinations of solutions, best meets the criteria and constraints? Make sure to provide your reasoning.

Solutions A, C, and D would probably preserve the most forest and protect biodiversity (criteria 1 and 4).

Solution E best meets criterion 2 by increasing the water quality of the lake.

Solutions C and D might help the villagers grow more food or have more money to buy food (criterion 3).

I would use a combination of solutions C, D, and E. This allows the villagers to stay in the area, grow more crops on existing land, and provide employment while improving the water quality of the lake. It also teaches new skills that can help with providing money for the villagers. The total cost would be $450,000 which meets the constraint.

6. How could the solution be improved? (You may adjust the criteria and the solutions)

I would spend the remaining money on educating the villagers on the importance of protecting the forest and how doing so benefits the village and the environment.
1. Describe the problem.

*Zebra mussels are an invasive species that affect biodiversity and ecosystem services. They have spread across the US and are now in states near Yellowstone.*

2. Describe the needs that the solution is to address.

*Prevent zebra mussels from becoming an invasive species in Yellowstone Lake.*

3. Identify the constraints that the solution must meet.

*Total budget cannot be more than $500,000.*

4. Identify the criteria that apply to the solution.

1. The biodiversity of the lake should be maintained. (Environmental)

2. Ecosystem services, such as boating and fishing, should be disrupted as little as possible. (Economic and social)

3. There should be the least chance of introducing any invasive species into the lake. (Environmental)
5. Which of the proposed solutions, or combinations of solutions, best meets the criteria and constraints? Make sure to provide your reasoning.

Solutions D and E do not meet criterion 1 very well as they will probably affect the food web of the lake. This will affect the biodiversity of the lake. Solution D also increases the chance of introducing an invasive species into the lake, which is against criterion 3.

Solution B does not fit well with criterion 2 as it has a negative effect on ecosystem services.

I suggest using a combination of solutions A, C, and F. If people are educated on what to look for they will do a better job of inspecting their boats and in monitoring the lake and river for zebra mussels. I did not choose solution G because I wanted to avoid adding chemicals to the environment as the chemicals could affect the organisms in and around the lake. My solutions would cost $400,000 which falls within the budget limit.

6. How could the solution be improved? (You may adjust the criteria and the solutions)

The main problem with solution C is that some boat owners may not carry out the inspections or not do them well. I would improve the solution by spending the money that is left over by making the boat inspections mandatory. I would also have the inspections checked and certified by an official who was trained on the zebra mussel problem.
### Designing a Solution

#### Activity 5.4
**Environmental Problem 4**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Describe the problem.</strong></td>
<td></td>
</tr>
<tr>
<td><em>The number of oysters in Chesapeake Bay has fallen to very low levels.</em></td>
<td></td>
</tr>
<tr>
<td><strong>2. Describe the needs that the solution is to address.</strong></td>
<td></td>
</tr>
<tr>
<td><em>Improve the quality of the water in Chesapeake Bay. Restore the biodiversity of the bay. Decrease the number of dead zones. Increase the oyster harvest in the bay.</em></td>
<td></td>
</tr>
<tr>
<td><strong>3. Identify the constraints that the solution must meet.</strong></td>
<td><strong>4. Identify the criteria that apply to the solution.</strong></td>
</tr>
<tr>
<td><em>Total budget cannot be more than $500,000.</em></td>
<td>1. <em>Reduce the number of dead zones as much as possible.</em> (Environmental)</td>
</tr>
<tr>
<td></td>
<td>2. <em>Decrease the nutrient-carrying runoff into the bay as much as possible.</em> (Environmental)</td>
</tr>
<tr>
<td></td>
<td>3. <em>Improve the water quality as much as possible.</em> (Environmental, economic, and social)</td>
</tr>
<tr>
<td></td>
<td>4. <em>Improve ecosystem services as much as possible.</em> (Economic and social)</td>
</tr>
<tr>
<td></td>
<td>5. <em>Improve the biodiversity of the bay.</em> (Environmental)</td>
</tr>
</tbody>
</table>
5. Which of the proposed solutions, or combinations of solutions, best meets the criteria and constraints? Make sure to provide your reasoning.

Solution A might meet criterion 3 because as the number of oysters increases, the water in the bay will be more filtered.

Solution B helps with criteria 3 and 4 as the new oysters would increase the oyster harvest and help filter more water. It doesn’t address the other criteria and it will affect the food web which would probably not work with criterion 5.

Solution E would help with criterion 4 as it will provide more employment but it doesn’t solve the other problems with the bay.

I would choose solutions C and D because they would help to reduce the runoff that is carrying nutrients into the bay. This would decrease the dead zones and would help more organisms to survive. This meets criteria 1, 2, and 5. The total cost would be $500,000 which is the maximum budget.

6. How could the solution be improved? (You may adjust the criteria and the solutions)

I would improve the solution by not having a total ban on fertilizers in communities with rivers and streams that drain into the bay. I would make those communities reduce the use of fertilizer. The new filtering systems should be able to clean nutrients from the runoff. This will help the bay. I would use the money that was saved to retrain some people on using other organisms instead of oysters in their businesses.
Chapter 5 Assessment

1. Seaside City has been a popular vacation spot for the past 25 years. Each year more tourists visit and more people come to live there. A wide range of organisms can be found in the sea near the city. The following food web shows you the feeding relationships between some of these organisms. Seaweed also provides a safe environment for many types of organisms not shown on the food web below.

Visitors love to watch the seals and dolphins. Both tourists and residents enjoy eating lobster or snapper at local restaurants. However, the increasing human population has led to increased demand for lobster and snapper. The table below provides data about the sea near Seaside City. The data indicate that both species have become overfished.

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of species in the sea near Seaside City</th>
<th>Number of lobsters per 10 square meters</th>
<th>Number of snappers per 10 square meters</th>
<th>Number of sea urchins per 10 square meters</th>
<th>Percentage of the sea with seaweed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>325</td>
<td>5</td>
<td>5</td>
<td>10</td>
<td>50</td>
</tr>
<tr>
<td>1995</td>
<td>324</td>
<td>3</td>
<td>3</td>
<td>15</td>
<td>40</td>
</tr>
<tr>
<td>2000</td>
<td>320</td>
<td>2</td>
<td>2</td>
<td>20</td>
<td>30</td>
</tr>
<tr>
<td>2005</td>
<td>315</td>
<td>1</td>
<td>1</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>2010</td>
<td>305</td>
<td>1</td>
<td>0.5</td>
<td>30</td>
<td>20</td>
</tr>
<tr>
<td>2015</td>
<td>285</td>
<td>0.5</td>
<td>0.5</td>
<td>35</td>
<td>15</td>
</tr>
</tbody>
</table>
a. In 2015 the people of Seaside City decided that the changes in this ecosystem were a problem. Two solutions were proposed. A short list of criteria and constraints were also developed by Seaside City. You were selected as one of the team of scientists and engineers to examine the solutions.

Read the proposed solutions and construct an argument that answers the question, "Which is the best proposed solution, based on the criteria, and why?"

**Proposed Solution A**

The sea near Seaside City would become a protected area, where no fishing is allowed. The area would extend 5 km (about 3 miles) out to sea and around the city. The cost of creating the protected area would be 1.5 millions dollars. Scientists estimate that it will take at least 20 years for the numbers of lobsters and snappers to recover to the 1990 levels. It is estimated that 250 fishing jobs would be lost. However, it is believed that tourism will increase by 20% because of the protected area. As the number of tourists increases, new hotels could be built, creating more jobs. New businesses, such as boat trips for tourists and scuba diving, could also be developed. It is estimated that at least 100 new jobs would be created over the next 5 years. Scientists expect that the number of species in the protected area will take about 30 years to recover to the level that it was in the year 2000.

**Proposed Solution B**

Five hundred lobsters and one thousand snappers will be brought from other parts of the country. The cost of introducing the species would be $200,000. They will be added to the ocean near Seaside City. They are different, but related, species from the lobsters and snappers that are found near Seaside City. The introduced species are larger and grow more quickly than the existing species. Sales tax will be increased by 1% to cover the cost of the bringing in the new lobsters and snappers. Divers will be used to catch and remove at least fifty percent of the sea urchins. There will not be a total ban on fishing, but fishing boats will only be allowed to fish during one week each month. It is estimated that 50 fishing jobs would be lost. It is expected to take about 10 years for the area to recover to the level that it was in the year 2005. Tourism is expected to remain the same during that time.
## Constraint:
The solution must cost less than 2 million dollars.

## Criteria:
1. Best recovery of the biodiversity of the ecosystem.
2. Lowest chance of introducing species that may become invasive.
3. Smallest number of job losses.
4. Shortest time for the ecosystem to recover.
b. Design your own solution. Explain why your solution is better than the solutions proposed by Seaside City.
1. Seaside City has been a popular vacation spot for the past 25 years. Each year more tourists visit and more people come to live there. A wide range of organisms can be found in the sea near the city. The following food web shows you the feeding relationships between some of these organisms. Seaweed also provides a safe environment for many types of organisms not shown on the food web below.

Visitors love to watch the seals and dolphins. Both tourists and residents enjoy eating lobster or snapper at local restaurants. However, the increasing human population has led to increased demand for lobster and snapper. The table below provides data about the sea near Seaside City. The data indicate that both species have become overfished.

### Seaside City Food Web

![Seaside City Food Web Diagram](image)

<table>
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<tr>
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a. In 2015 the people of Seaside City decided that the changes in this ecosystem were a problem. Two solutions were proposed. A short list of criteria and constraints were also developed by Seaside City. You were selected as one of the team of scientists and engineers to examine the solutions.

Read the proposed solutions and construct an argument that answers the question, “Which is the best proposed solution, based on the criteria, and why?”

**Proposed Solution A**

The sea near Seaside City would become a protected area, where no fishing is allowed. The area would extend 5 km (about 3 miles) out to sea and around the city. The cost of creating the protected area would be 1.5 millions dollars. Scientists estimate that it will take at least 20 years for the numbers of lobsters and snappers to recover to the 1990 levels. It is estimated that 250 fishing jobs would be lost. However, it is believed that tourism will increase by 20% because of the protected area. As the number of tourists increases, new hotels could be built, creating more jobs. New businesses, such as boat trips for tourists and scuba diving, could also be developed. It is estimated that at least 100 new jobs would be created over the next 5 years. Scientists expect that the number of species in the protected area will take about 30 years to recover to the level that it was in the year 2000.

**Proposed Solution B**

Five hundred lobsters and one thousand snappers will be brought from other parts of the country. The cost of introducing the species would be $200,000. They will be added to the ocean near Seaside City. They are different, but related, species from the lobsters and snappers that are found near Seaside City. The introduced species are larger and grow more quickly than the existing species. Sales tax will be increased by 1% to cover the cost of the bringing in the new lobsters and snappers. Divers will be used to catch and remove at least fifty percent of the sea urchins. There will not be a total ban on fishing, but fishing boats will only be allowed to fish during one week each month. It is estimated that 50 fishing jobs would be lost. It is expected to take about 10 years for the area to recover to the level that it was in the year 2005. Tourism is expected to remain the same during that time.
Constraint: The solution must cost less than 2 million dollars.
Criteria: 1. Best recovery of the biodiversity of the ecosystem.
2. Lowest chance of introducing species that may become invasive.
3. Smallest number of job losses.
4. Shortest time for the ecosystem to recover.

I believe that proposal A is the best solution. Both proposals fall within the constraint of costing less than $2,000,000.
Proposal A meets criteria 1 and 2 better than Proposal B. However, Proposal B meets criteria 3 and 4 better than Proposal A. Proposal A creates a protected area where no fishing is allowed. This is a good environmental solution and would allow the ecosystem to recover more fully than Proposal B, although it would take about 30 years to do so.
Proposal B is a quicker solution as it involves importing 500 lobsters and 1,000 snappers. I think this could be a problem as these organisms are not native to the area and could affect populations of native species. They might even become invasive. It is therefore possible that the ecosystem will not recover well and may undergo more changes. This is why I believe that Proposal A is a better solution than Proposal B. The biggest problem with Proposal A is that more jobs will be lost than with Proposal B. It is estimated that 250 fishing jobs would be lost and 100 new jobs created because of increased tourism. This means that there would be a loss of about 150 jobs compared to an estimated job loss of 50 fishing jobs with Proposal B. This would cause increased negative social and economic consequences compared to Proposal B.
However, I believe that if the ecosystem changed because of the introduction of non-native species under Proposal B, there is a risk that there could be more job losses in future years. Therefore, I believe Proposal A is still the better choice.
b. Design your own solution. Explain why your solution is better than the solutions proposed by Seaside City.

I think it is most important that the area fully recovers. I don’t think it matters if it takes longer for it to recover, so I would remove criterion 4. I also think that criterion 1 is more important than 3. So I don’t think the best solution has to be the one that has the fewest job losses.

I would modify Proposal A by making the protected area a little smaller and allowing limited fishing just outside the area. However, I would put limits on the amount of fish and lobsters that they can catch. Having the protected area will attract more tourists and this will create more jobs. Allowing limited fishing will reduce the number of fishing jobs that are lost. By maintaining ecosystem services such as tourism and fishing, this solution is better than Solution A from an economic and social perspective. This is also better than Solution B from an environmental perspective because it does not introduce any non-native species.
Chapter 5 Assessment
Student Checklist

1a. □ Claim
    □ Evidence (numbers or trends from proposed solutions)
    □ Reasoning

1b. □ New solution is proposed (needs to be different than initial solutions)
    □ Explains why solution is better than previous solution
**Scoring guide for Chapter 5 Assessment**

*Note:* The rubrics below are drafts. They are intended as guides for assessing whether your students are achieving learning goals. We encourage you to use a scoring system that works in your classroom context and that is appropriate for the level of your students. So, for example, students may be able to earn a “full credit” score for a “Level 2: Developing” response.

**a.** Construct an argument that answers the question, “Which is the best proposed solution, based on the criteria, and why?”

<table>
<thead>
<tr>
<th>Claim</th>
<th>Level 4: Advanced</th>
<th>Level 3: Proficient</th>
<th>Level 2: Developing</th>
<th>Level 1: Beginning</th>
<th>Level 0: Not evident</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N/A</td>
<td>Claim completely answers the question e.g. “Proposal B best meets the criteria” OR “Proposal A best meets the criteria”</td>
<td>Claim partially answers the question</td>
<td>Claim does not answer the question</td>
<td>Does not make a claim</td>
</tr>
</tbody>
</table>

**Evidence**

<table>
<thead>
<tr>
<th>Evidence</th>
<th>Level 4: Advanced</th>
<th>Level 3: Proficient</th>
<th>Level 2: Developing</th>
<th>Level 1: Beginning</th>
<th>Level 0: Not evident</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Provides appropriate evidence to support the claim. e.g. Proposal B will remove at least 50% of the sea urchins using divers. 500 lobsters and 1,000 snappers will also be brought to the area from a different part of the country. These will eat more of the sea urchins. In addition fishing will be limited to one week per month. These measures will help the area to recover more quickly than in Proposal A. Also, proposal B produces less disruption to ecosystem services and 100 fewer people would lose their jobs than in Proposal A.</td>
<td>Provides appropriate evidence to support the claim. May include some inappropriate evidence.</td>
<td>Provides evidence that actually supports a different claim, but not the one selected.</td>
<td>Provides inappropriate evidence (evidence does not support the claim selected or a counter claim).</td>
<td>Does not provide evidence.</td>
</tr>
<tr>
<td>Scientific Reasoning</td>
<td>Level 4: Advanced</td>
<td>Level 3: Proficient</td>
<td>Level 2: Developing</td>
<td>Level 1: Beginning</td>
<td>Level 0: Not evident</td>
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<td></td>
<td>Appropriately uses relevant science concepts to thoroughly evaluate the evidence provided and support the selected claim. e.g. The better proposal will be the one that allows the ecosystem to recover without too much disruption to humans. The best balance of these factors is Proposal B. There is a possibility that the lobsters and snappers could be invasive, but the benefits outweigh the costs.</td>
<td>Uses science concepts to evaluate the evidence provided to support the selected claim. May include some additional or inappropriate evidence and/or science concepts.</td>
<td>Uses inappropriate science concepts to evaluate the evidence provided.</td>
<td>Evaluates the evidence provided without mention of science concepts. For example, states evidence is good but does not explain why.</td>
<td>Does not evaluate the evidence.</td>
</tr>
</tbody>
</table>
### Scoring guide for Chapter 5 Assessment  Continued

**b.** Design your own solution. Explain why your solution is better than the solutions proposed by Seaside City.”

<table>
<thead>
<tr>
<th>Level 4: Advanced</th>
<th>Level 3: Proficient</th>
<th>Level 2: Developing</th>
<th>Level 1: Beginning</th>
<th>Level 0: Not evident</th>
</tr>
</thead>
<tbody>
<tr>
<td>New solution has clear benefits over Proposal A or Proposal B e.g. I would modify Proposal A by making the protected area a little smaller and allowing limited fishing just outside the area. However, I would put limits on the amount of fish and lobsters that they can catch. Having the protected area will attract more tourists and this will create more jobs. Allowing limited fishing will reduce the number of fishing jobs that are lost. By maintaining ecosystem services such as tourism and fishing, this solution is better than Solution A from an economic and social perspective. This is also better than Solution B from an environmental perspective because it does not introduce any non-native species. I think it is most important that the area fully recovers. I don’t think it matters if it takes longer for it to recover, so I would remove criterion 4. I also think that that criterion 1 is more important than 3. So I don’t think the best solution has to be the one that has the fewest job losses.</td>
<td>A new solution is proposed, but the benefits over Proposal A or Proposal are not clear</td>
<td>Student attempts to provide a new solution</td>
<td>Student restates a previous solution</td>
<td>Student does not provide a solution</td>
</tr>
</tbody>
</table>
Disruptions in Ecosystems

Ecosystem Interactions, Energy, & Dynamics

Middle School Unit aligned with the Next Generation Science Standards

Teacher Materials
Third Field Test Version
Disruptions in Ecosystems

Ecosystem Interactions, Energy, & Dynamics

CHAPTER 1
Wolves in Yellowstone

CHAPTER 2
Ecosystem Models

CHAPTER 3
Interactions between Populations & Resources

CHAPTER 4
Zebra Mussels

CHAPTER 5
Designing Solutions

Third Field Test Version
Middle School Unit aligned with the Next Generation Science Standards

This material is based upon work supported by the National Science Foundation under Grant # NSF DRL 1418235. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.
What are some of the ways to deal with an insect problem?
This chapter engages students with a phenomenon that is woven throughout this unit, that of humans using more and more resources which causes environmental problems and thus creates the need for the development of solutions. Students begin the chapter by looking at a particular environmental problem, that of a crop infestation. They consider various solutions to the problem and discuss the advantages and disadvantages of each. In doing so they learn that for each course of action there are consequences, some foreseen and some not.

How can we balance human needs with those of the environment?
Human impact plays an important role in this activity as students play a game where each member of a group manages a connected area of a fictitious community. As a group they make decisions that affect ecosystem services and the environment, concepts that were introduced in the previous chapter. Each decision has consequences, some of them immediate and some delayed. Some of the consequences are also unanticipated by the group. By the end of the game, students realize that balancing environmental needs with human needs can be difficult.

What factors should be considered when choosing, or designing, a solution to an environmental problem?
Students revisit the previous two activities as they analyze the impacts of decisions made in terms of the effects on the environment, people, and communities. They learn that solutions are designed to operate within constraints and that criteria are used to develop or choose the optimal solution. Finally, they apply criteria and constraints as they use a framework to evaluate potential solutions to the crop infestation problem from an environmental, economic, and social perspective.

How can we evaluate solutions to decide how well they might work?
In the previous activity, students were introduced to a system that could be used in designing and evaluating solutions. In this Elaborate activity they apply the system to potential solutions for real world environmental problems. They develop and use environmental, economic, and social criteria to choose the best combination of solutions that fall within the limits of identified constraints. They complete the activity by suggesting refinements to their solutions.

How can the negative impact of humans on coral reefs be reduced?
Students are introduced to a broad range of threats to coral reefs around the world. They draw upon their understanding of designing solutions as groups develop and present a solution to one of the threats. As part of their presentation, groups make an argument for why their solution is a good response to minimizing human impact on the reef. After the presentations the class evaluates how well the solutions meet the specified criteria and constraints and how the threat illustrates how increases in human populations and resource use negatively impact the environment.
### Chapter 5 Overview

#### Activities

<table>
<thead>
<tr>
<th>Engage</th>
<th>5.1 Solving a Problem</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guiding Question: What are some of the ways to deal with an insect problem? Students examine a fictitious scenario of an insect infestation at a farm. They brainstorm possible solutions before discussing the advantages and disadvantages of four actual solutions that have been tried at different times and places. The class then watches a short video about one of the solutions - the introduction of the cane toad into Australia and the unexpected consequences of the introduction.</td>
<td></td>
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<tr>
<td>Science Concepts</td>
<td>MS.LS2.C MS.LS4.D MS.ESS3C Connections to the Nature of Science</td>
</tr>
<tr>
<td>Science Practices</td>
<td>Asking Questions and Defining Problems</td>
</tr>
<tr>
<td>Science Vocabulary</td>
<td>invasive species</td>
</tr>
<tr>
<td>Teaching Periods</td>
<td>1</td>
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</table>

<table>
<thead>
<tr>
<th>Explore</th>
<th>5.2 Stability and Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guiding Question: How can we balance human needs with those of the environment? Students act the role of managers of adjacent environmental areas in a simulated environment. Each group of four managers makes decisions that affect the areas. These decisions have both short and long term consequences. Students track the effects of the group's decisions by recording changes to their environmental, money, and happiness points.</td>
<td></td>
</tr>
<tr>
<td>Science Practices</td>
<td>Developing and Using Models Analyzing and Interpreting Data</td>
</tr>
<tr>
<td>Science Vocabulary</td>
<td>ecosystem services environmental</td>
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<tr>
<td>Teaching Periods</td>
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<table>
<thead>
<tr>
<th>Explain</th>
<th>5.3 Designing Solutions</th>
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</thead>
<tbody>
<tr>
<td>Guiding Question: What factors should be considered when choosing, or designing, a solution to an environmental problem? Students design a solution to the crop infestation problem by evaluating how well various courses of action meet the designated criteria and constraints, and how each addresses environmental, economic, and social considerations. In doing so, students realize that solutions to environmental problems often involve trade-offs and that decisions are influenced by more than scientific considerations.</td>
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<tr>
<td>Science Concepts</td>
<td>MS.ETS1.B MS.ESS3.C Connections to Engineering, Technology, and Applications of Science Connections to the Nature of Science</td>
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<td>Science Practices</td>
<td>Constructing Explanations and Designing Solutions</td>
</tr>
<tr>
<td>Science Vocabulary</td>
<td>criteria constraints economic social</td>
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<tr>
<td>Teaching Periods</td>
<td>2</td>
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</tbody>
</table>
### Elaborate

#### 5.4 Evaluating Solutions

**Guiding Question:** How can we evaluate solutions to decide how well they might work?

Groups are assigned a current environmental problem. They brainstorm solutions and develop a criterion-based system which they use to rank their solutions from best to worst. Groups then use the same system to evaluate several solutions to their assigned problem. They suggest a solution to the problem, which may be a combination of previously examined solutions.

<table>
<thead>
<tr>
<th>Science Concepts</th>
<th>Science Practices</th>
<th>Science Vocabulary</th>
<th>Teaching Periods</th>
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<td>Cause &amp; Effect</td>
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<tr>
<td>Connections to the Nature of Science</td>
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</table>

### Evaluate

#### 5.5 Coral Reefs

**Guiding Question:** How can the negative impact of humans on coral reefs be reduced?

Groups choose a threat to the health of coral reefs that is caused by humans. They design a solution to reduce or minimize the threat and present it to the class. They evaluate each of the solutions presented and construct an argument for the one that is most effective and sustainable.

<table>
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<th>Teaching Periods</th>
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<tr>
<td>MS.LS4.D</td>
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<td>services</td>
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## Assessment Overview

<table>
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<tr>
<th>Embedded Formative Assessment</th>
<th>Activity 1 Engage</th>
<th>Activity 2 Explore</th>
<th>Activity 3 Explain</th>
<th>Activity 4 Elaborate</th>
<th>Activity 5 Evaluate</th>
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<td>Analysis 4</td>
<td>Analysis 3</td>
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* Primary PE and supporting elements  ** Secondary PE and supporting elements  *** Tertiary PE and supporting elements
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<tr>
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<th>Activity 1 Engage</th>
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<td>CCSS Math</td>
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</table>

* Primary PE and supporting elements  ** Secondary PE and supporting elements  *** Tertiary PE and supporting elements

** PE**

** MS LS2-C** Evaluate competing design solutions for maintaining biodiversity and ecosystem services.

** MS ESS3-3** Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

** MS ESS3-4** Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth’s systems.

** DCI**

** MS LS2-C** Biodiversity describes the variety of species found in Earth’s terrestrial and oceanic ecosystems. The completeness or integrity of an ecosystem’s biodiversity is often used as a measure of its health.

** MS LS4-D** Changes in biodiversity can influence humans’ resources, such as food, energy, and medicines, as well as ecosystem services that humans rely on—for example, water purification and recycling.

** MS ETS1.B** There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem.

** MS ESS3-C** Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth’s environments can have different impacts (negative and positive) for different living things.

** MS ESS3-C/** ** Typical as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.

** SEP**

** EAE** Evaluate competing design solutions based on jointly developed and agreed-upon design criteria.

** CEDS** Apply scientific principles to design an object, tool, process, or system.

** EAE** Construct an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.
<table>
<thead>
<tr>
<th>CCC</th>
<th>S&amp;C*  Small changes in one part of a system might cause large changes in another part.</th>
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<tbody>
<tr>
<td></td>
<td>(CET&amp;S)** The use of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Thus, technology use varies from region to region and over time.</td>
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<tr>
<td></td>
<td>(CNoS)<strong>/</strong>* Scientific knowledge can describe the consequences of actions but does not necessarily prescribe the decisions that society takes.</td>
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<td></td>
<td>C&amp;E** Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation.</td>
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<tr>
<td></td>
<td>C&amp;E*** Cause and effect relationships may be used to predict phenomena in natural or designed systems.</td>
</tr>
<tr>
<td></td>
<td>(CET&amp;S)<strong>/</strong>* All human activity draws on natural resources and has both short- and long-term consequences, positive as well as negative, for the health of people and the natural environment.</td>
</tr>
<tr>
<td>CC ELA</td>
<td>WHST.6-8.1*** Write arguments focused on discipline-specific content.</td>
</tr>
<tr>
<td>CC Math</td>
<td>(MP.4)* Model with mathematics.</td>
</tr>
</tbody>
</table>
What are some of the ways to deal with an insect problem?

This chapter engages students with a phenomenon that is woven throughout this unit, that of humans using more and more resources which causes environmental problems and thus creates the need for the development of solutions. Students begin the chapter by looking at a particular environmental problem, that of a crop infestation. They consider various solutions to the problem and discuss the advantages and disadvantages of each. In doing so they learn that for each course of action there are consequences, some foreseen and some not.

Rationale & NGSS Integration

The previous chapters in this unit examined various ecosystem disruptions. Although this theme is continued in this final chapter, the focus shifts towards students examining and evaluating potential solutions. During this chapter, students will employ the science and engineering practice of evaluating solutions for maintaining biodiversity and ecosystem services. They will interact with the crosscutting concepts of cause and effect and stability and change as they identify cause and effect relationships and examine or suggest methods to minimize the changes experienced by ecosystems. A common thread throughout this chapter relates to the aspect of the nature of science that pertains to the understanding that “when making decisions scientific knowledge can describe the consequences of actions but does not necessarily prescribe the decisions to take.” Understanding the disciplinary core ideas of human impact on the environment, biodiversity, and ecosystem services will help inform the solutions that students develop and evaluate.

Activity Overview

In this Engage activity students examine a fictitious scenario of an insect infestation at a farm. They brainstorm possible solutions before discussing the
advantages and disadvantages of four actual solutions that have been tried at different times and places. The class then watches a short video about one of the solutions - the introduction of the cane toad into Australia and the unexpected consequences of the introduction.

**Key Vocabulary**

invasive species

**Materials and Advance Preparation**

**For the teacher**

- Access to computer with Internet connection
  
  Preview the video clip on cane toads available at the link below and cue up the video. The link to the segment follows:
  
  http://www.nationalgeographic.org/media/cane-toads/

- 1 large computer monitor or projector

**For each student**

- Handout 5.1-1, “Control Methods”

**Teaching Summary**

**Getting Started**

1. Students read the scenario and brainstorm questions.

**Doing the Activity**

2. Students examine ways to solve the insect problem.

3. Students recommend a solution.

**Follow-Up**

4. (Assessment) Students watch a video segment about the cane toad invasion in Australia.

5. Preview the chapter and revisit the Guiding Question.
References


Teaching Suggestions

Getting Started

1. **Students read the scenario and brainstorm questions.** (15 minutes)

   a. Have students read the scenario at the beginning of the activity or read it aloud.

   The fictitious scenario is used to engage students and set the context for this chapter, that of designing solutions to environmental problems. Encourage students to use their imaginations to picture themselves living on the farm depicted in the scenario, tasked with helping the family think through possible solutions. Although the scenario is fictitious, it is based on an historical example, as described later in this Guide. Be careful not to reveal information related to the historical insect infestation problem prematurely. To do so would inhibit eliciting student’s ideas which is a key component of the Engage phase.
b. Begin to create a KWL chart by asking the class what they know from the scenario.

Write students’ responses in the K column of the KWL chart, (Holly is a middle school student who lives on a farm; the farm has an insect problem, etc.) For more information on the use of KWL charts see the More Information section at the end of this activity.

c. Have students work in groups of four to complete Procedure Step 1.

d. Write students’ responses on the W column of the KWL chart during Procedure Step 2.

Students may come up with questions similar to the following: what type of crop; what type of insect; what the family has already tried to do, etc.? This is an opportunity for students to engage in the practice of asking questions as they attempt to define the problem.

e. Provide a limited amount of additional information in the L column of the KWL.

Use the following bullet points to provide more information, if relevant to the questions asked by the class:

• The climate in the region is mainly hot and dry, with periods of heavy rain.
• The crops are mainly sugar cane, with smaller amounts of corn and sweet potatoes.
• The beetle is damaging all of these crops.
• Sugar cane grows up to 6 to 8 m high.
• The crops generate income for the family.
• The crops are important to the community because the farm hires workers and purchases products and services from local businesses.
• The adult beetle feeds on the top of the crops.
• The larvae of the beetle (grubs) burrow into the ground and eat the roots of the crops.
• The beetles damage structures, such as buildings, by burrowing into soft materials such as caulking or sealants.
**Doing the Activity**

2. **Students examine ways to solve the insect problem.** (15 minutes)

   a. Ask the class to identify the problem and the needs of a solution.

       Guide a short discussion as necessary so that students identify the problem as the insects damaging the crops. Suggestions as to what the solution should address may vary. For example, students may suggest that all of the insects need to be removed or that all of the crops must recover.

   b. Provide a few minutes for groups to brainstorm ways of solving the insect problem.

       Begin by telling the class that at this stage there are no right answers to the problem. Allow a few minutes for brainstorming and then allow groups to share their ideas. Do not comment on their ideas just yet. Make a note to yourself of misconceptions students have so that you can revisit them when the students are further through the chapter. At that point students will be better able to correct many misconceptions through their own growth in understanding.

   c. Give a copy of Handout 5.1-1 to each student.

       Explain that the handout describes four solutions to the insect problem that have actually been tried somewhere in the world. Explain that each group is to discuss the advantages and disadvantages of each solution and to write them in the appropriate place on the handout.

3. **Students recommend a solution.** (5 minutes)

   a. Ask each group to recommend the solution that they think is best for Holly’s family.

       Accept any solution but make sure that groups provide the reasoning for their choice. You may want to tally which solutions each group chose to see which solution was favored by the class.

   b. Ask students to consider how their choice of solution would affect the environment, the family, and the community.

       Encourage students to think about environmental consequences (such as harm to other organisms), costs (such as how expensive a treatment might be), and effect on the family and community (for example, loss of jobs or home). This is a precursor to developing a system to evaluate solutions and will be developed further in the next activity.
Follow-Up

4. Students watch a video segment about the cane toad invasion in Australia. (10 minutes)

   a. (Assessment) Discuss Analysis questions 1 and 2 with the class.

      Allow time for a short discussion of each question. Analysis question 2 provides an additional opportunity for students to engage in the science and engineering practice of asking questions and defining problems.

   b. Direct students’ attention to Analysis question 3.

      Explain to the class that the insect problem described in the scenario is based on a real problem that occurred in the sugar cane fields in Queensland, Australia in the 1930’s.

      Point out that cane toads were introduced to control the insects that were destroying the crops. The cane toads had been used successfully in other countries but had never been introduced to Australia.

   c. Show the video and briefly discuss the meaning of biological control.

      Explain that biological control involves using another organism to try to solve a problem. In this case, the cane toad was used to try to solve the insect problem.

   d. Refer students’ back to Analysis question 3.

      Ask the class to think back to the zebra mussel in Chapter 4 and try to recall the term used when describing a non-native species that causes harm to the environment, human health, or the economy (an invasive species).

   e. Summarize the insect infestation problem and the use of biological control.

      Prompt students to consider how a solution may address one aspect of a problem but can cause other problems. They will encounter this idea further in Activity 2 where they will make decisions to solve problems. They will see that each decision has consequences, some intended and some unanticipated. Ask students to reflect about when they (or someone that they know) may have made a decision that had unintended consequences. Allow students to share their thoughts.

5. Preview the chapter and revisit the Guiding Question. (5 minutes)

   a. Preview the chapter with the students.

      Use the Chapter Overview to guide you as you preview the rest of
the chapter with the class. Tell students the guiding question for the chapter, “How can the effects of environmental problems be reduced?” and briefly preview the content they will be learning, including the disciplinary core ideas, and the crosscutting concepts and science and engineering practices they will use to build conceptual understanding.

Explain to students that the main learning goals for this chapter are: 1) to evaluate competing design solutions (based upon jointly developed and agreed-upon design criteria), 2) apply scientific principles to design a process, and 3) construct an oral argument to support or refute a solution to a problem. Tell students that they will engage in these practices as they encounter a variety of environmental problems.

b. Revisit the guiding question.

Conclude the activity by revisiting the Guiding Question, “What are some of the ways to deal with an insect problem?” Draw students’ attention to the ideas that “when making decisions scientific knowledge can describe the consequences of actions but does not necessarily prescribe the decisions to take.” (From Connections to the Nature of Science in the Crosscutting Concepts strand.) Analysis question 1 can be used to frame a conversation around whether scientific knowledge is the only basis on which environmental decisions are made. Help students realize that none of the four solutions they examined were without drawbacks. This will be a recurrent theme throughout this chapter.

Suggested Answers To Analysis

**NOTE:** Analysis questions marked with (Assessment) are suggested opportunities to check for student understanding. Hints for using the questions are included with the suggested answers.

1. **What factors did you consider when deciding which solution to recommend?**

   **Assessment – CCC – Connections to the Nature of Science**
   This question provides an opportunity to gauge students’ initial understanding of the idea that scientific knowledge can describe the consequences of actions but does not necessarily prescribe the decisions that society takes (CNoS). The intent of this question is to foreshadow the concept of a solution that meets humans and environmental needs which is introduced in Activity 3. At this stage it is sufficient to discuss students’ responses and potentially organize them into categories such as environmental impact and human impact.
Activity 5.1

Students’ answers will vary. Some may look for the most effective environmental solution. Others may consider how much Holly and her family were affected.

2. **What other information would have been useful when you were examining solutions?**

   Student’s responses will vary. Some may suggest that knowing the actual costs of the solutions would have made it easier to compare them. Others suggestions might include having more information about past successes of the solutions, or detailed information about the toad and the environment or the pesticide, etc.

3. **Holly’s story is based on a real-life problem. Your teacher will give you more information about the problem and the solution that was tried. Describe how the solution relates to an environmental problem that you have studied in this unit.**

   The solution that was tried was the introduction of cane toads. The cane toad became an invasive species in Australia. We studied an invasive species (zebra mussels) in the last chapter.

More Information

**KWLs**

A KWL is a three-column chart with the headings K, W, and L. The letters KWL refer to the three sections of the strategy that ask, “What do I Know? What do I Want to Know? What did I Learn?” KWLs help students process and apply the information that they encounter in readings and investigations.

**Science Content Information**

The cane toad (Bufo marinus) is a large and poisonous animal that is native to Central and South America. Since the toad had been introduced to various regions in the world in an attempt to control pests in cane fields, Australian authorities approved importation of cane toads to the Australian province of Queensland in 1935. About 100 were shipped in, allowed to breed in captivity, and were released into several sugar plantations where two types of beetles were ruining the crop.

Although the cane toads would certainly eat the beetles, it turned out that they didn’t encounter the beetles frequently enough to eat many of them. One reason is that the beetles lived mainly in the higher parts of the sugar cane plants out of the toad’s jumping range. Another reason is that the beetle only invaded the sugar cane fields at the time of year when the cane toad didn’t go there because of the lack
of protective plant cover. In addition, the beetles were most active during the day, but the cane toads fed mainly at night. The cane toads didn’t go hungry though, as they ate pretty much anything that would fit into their mouths – including insects, frogs, small reptiles, mammals, and birds – eventually diminishing the biodiversity of the areas they were invading.

A female cane toad can produce around 35,000 eggs every time she mates, which can happen several times a year. Because cane toads can survive in a wide range of conditions, they adjusted well to the environment in Queensland. They can also travel 50 km in a single day and have spread to other parts of Australia. They have no natural predators in Australia, and most predators that do attempt to eat them die of heart failure since the adults have poison glands in their skin. Cane toads have a voracious appetite and can feed as often as 200 times a night. The current cane toad population is estimated to be over 200 million. This invasive species has caused significant disruptions to ecosystems throughout the northern and eastern parts of Australia.

**Teaching Information**

As this is an Engage activity the focus of the lesson is not on choosing the “right” solution, nor is it about understanding details of the cane toad story. The instructional strategies used in this lesson should be consistent with eliciting prior knowledge, such as through the use of discussion – think-pair-share, small group, large group, KWL charts, etc. The lesson is also designed to engage students, raise their curiosity, and help them raise questions of their own. The short video clip will certainly be engaging but it is also critical that the pace of the lesson is such that student interest is maintained. Suggested times for each part of the activity are provided in the Teaching Suggestions. It can be tempting to spend a lot of time responding to students’ questions as their curiosity is piqued but the lesson will be a more effective and memorable learning experience if the pace is brisk and consistent enough so that it can be completed in a single 50 minute period.
Activity 5.1
Activity 5.1

**Engage: Solving a Problem**

**Materials and Advance Preparation**

**For the teacher**

- Access to computer with Internet connection

  *Preview the video clip on cane toads available at the link below and cue up the video. The link to the segment follows: http://www.nationalgeographic.org/media/cane-toads/*

- 1 large computer monitor or projector

**For each student**

- Handout 5.1-1, “Control Methods”

**Teaching Suggestions**

1. **Students read the scenario and brainstorm questions.** (15 minutes)
   
   a. Have students read the scenario at the beginning of the activity or read it aloud.
   
   b. Begin to create a KWL chart by asking the class what they know from the scenario.
   
   c. Have students work in groups of four to complete Procedure Step 1.
   
   d. Write students’ responses on the W column of the KWL chart during Procedure Step 2.
   
   e. Provide a limited amount of additional information in the L column of the KWL.

2. **Students examine ways to solve the insect problem.** (15 minutes)
   
   a. Ask the class to identify the problem and the needs of a solution.
   
   b. Provide a few minutes for groups to brainstorm ways of solving the insect problem.
   
   c. Give a copy of Handout 5.1-1 to each student.

3. **Students recommend a solution.** (5 minutes)
   
   a. Ask each group to recommend the solution that they think is best for Holly’s family.
b. Ask students to consider how their choice of solution would affect the environment, the family, and the community.

Follow-Up

4. **Students watch a video segment about the cane toad invasion in Australia.** (10 minutes)
   a. (Assessment) Discuss Analysis questions 1 and 2 with the class.
   b. Direct students’ attention to Analysis question 3.
   c. Show the video and briefly discuss the meaning of biological control.
   d. Refer students’ back to Analysis question 3.
   e. Summarize the insect infestation problem and the use of biological control.

5. **Revisit the Guiding Question.** (5 minutes)
   a. Preview the chapter with the students.
   b. Revisit the guiding question.
Stability and Change

How can we balance human needs with those of the environment?

Human impact plays an important role in this activity as students play a game where each member of a group manages a connected area of a fictitious community. As a group they make decisions that affect ecosystem services and the environment, concepts that were introduced in the previous chapter. Each decision has consequences, some of them immediate and some delayed. Some of the consequences are also unanticipated by the group. By the end of the game, students realize that balancing environmental needs with human needs can be difficult.

Rationale & NGSS Integration

In the previous activity students saw that each proposed solution had advantages and disadvantages. This Explore activity continues developing that concept as students are challenged to manage assigned environmental areas in such a way that the decisions that they make cause as few detrimental effects as possible. Students interact with the core idea of human activities impacting the environment in both positive and negative ways. They also engage with the crosscutting concepts of cause and effect, stability and change, the nature of science, and connections to engineering, technology, and applications of science.

As they make decisions, students will see that sometimes what is good for people is not great for the environment. They do this when, after each decision, they add or subtract points in three categories – environmental, economic, and social. The latter two categories specifically relate to effects on humans. The process of examining effects from both an environmental and human perspective is used in the remaining activities of this chapter as students first evaluate, and later design, solutions.
Activity Overview

In this Explore activity students act the role of managers of adjacent environmental areas in a simulated environment. Each group of four managers makes decisions that affect the areas. These decisions have both short and long term consequences. Students track the effects of the group’s decisions by recording changes to their environmental, money, and happiness points.

Key Vocabulary

ecosystem services  environmental

Materials and Advance Preparation

For each group of four students

- 1 set of 6 Round 1 event cards*
- 1 set of 5 Round 2 event cards*
- 1 set of 4 Round 3 event cards*
- 1 map

*Note that each group needs four Event cards for each Round. Six Round 1 cards and five Round 2 cards have been provided. This allows for some differences in experiences between groups. Shuffle (or have students shuffle) each set of Event cards before use.

For each student

- Handout 5.2-1, “Score Sheet”

** You may want to prepare a second set of Handout 5.2-1, “Score Sheet” for each class. They will use one sheet during the practice and will likely need a fresh sheet for the actual game.

Teaching Summary

Getting Started

1. Discuss ways in which humans impact the environment.
Doing the Activity

2. Students learn the rules of the game in a practice round.
3. Groups complete playing three rounds of the game.

Follow-Up

4. (Assessment) Discuss the patterns shown by the scores from the game.
5. Revisit the Guiding Question.

Teaching Suggestions

Getting Started

1. **Discuss ways in which humans impact the environment.** (15 minutes)
   
   a. Ask the class to describe examples from previous chapters where humans have had an impact on the environment.

   Ask the class to think about what they have learned in the unit so far and to describe examples of ways that humans impact the environment. They may suggest hunting and wolf reintroduction from Chapter 1, overfishing and dead zones from Chapter 3, and introducing invasive species from Chapter 4. Ask students to think of other examples that they know of but have not been included in the unit. Examples might include pollution, building structures, building roads, damming rivers, etc.

   b. Confirm that human actions often have consequences for the environment.

   Summarize this part of the lesson by confirming that human actions often have consequences for the environment. Sometimes these consequences are known and sometimes they are unknown, sometimes the effects are short-term and sometimes they are long-term.

   c. Introduce the game.

   Explain that in this activity they will play a game where members of the group will manage different but related environmental areas. They will make various decisions and will measure the consequences by recording a score in a table. Their challenge is to manage their area so that it is in a better condition at the end of the game than at the beginning.
Activity 5.2

Doing the Activity

2. **Students learn the rules of the game in a practice round.** (20 to 25 minutes)

   a. Organize students into groups of four.

      For this activity, students will work in groups of four. If you have groups with less than four it is possible for a student to manage more than one area. If you have to create a group with more than four students it is possible for a pair of students to manage an area together. Remind students that effective group work is essential as they engage in scientific and engineering practices. For more suggestions on group work, see the More Information section at the end of this activity.

   b. Distribute the map and Handout 5.2-1, “Score Sheet.”

      Explain that the first thing to do is for each student to select one of the four areas on the map. This will be the environmental area that they manage. Discuss the score sheet with the class, pointing out that there are three rounds in the game and three columns in which to record scores. Explain that the scores in the table are an indication of the conditions of the area - the higher the numbers, the better the conditions.

   c. Explain how to use the Event cards and the scoring system.

      Project one of the Event cards from Round 1 so that students can see the format. Point out that at the top of the card there is a description of an action that the group will decide whether to approve or to ignore. The tables on the cards show how the effects of their decision will affect each of the point columns. This provides a simple numerical representation of cause and effect. Spend a little time discussing what the three columns represent. Environmental points provide an indication of how healthy the environment is. Money points reflect how strong the local economy is (whether people and businesses have money), and happiness points reflect how satisfied (and happy) the local people are.

      Consider drawing symbols to represent the meaning of each of the columns. For example, use a tree to represent the environment, a dollar sign to represent money, and a smiley face to represent happiness. These may help students to better connect the terms with their meaning. In the next activity, the terms “money” and “happiness” will be replaced by “economic” and “social.” You can reinforce the connection between money and economic, and between happiness and social, by using the same set of symbols in both activities.

   d. Direct students’ attention to Process and Procedure Step 4.
Explain that the person who takes the card should read the Action item and the choices. Emphasize that they should NOT tell the rest of the group the information about how the scores change in the tables on the card. Point out that in Step 5 the other members of the group should predict whether the scores will increase or decrease based on the possible choices. Members of the group should then make a choice and the card reader should reveal how the scores in each column should be adjusted based on the decision made. Make sure that the role of the card taker/reader rotates with each new card, so that all members of the group have a chance to read and also to predict.

e. Allow groups time to play a practice round.

Hand out the Round 1 Event cards and allow groups to try playing and scoring a couple of events. Monitor groups to see which ones need help and which have got the hang of the game. Allow the class to ask clarifying questions regarding game play and scoring. Consider whether to hand out the remaining Event cards and allow students to continue or whether to collect the cards and start again the next day.

This is a suitable place to end day 1 of this activity.

3. **Groups complete playing three rounds of the game.** (30 to 40 minutes)

   a. When confident that the class understands how to play the game, hand out a full set of Event cards for all three rounds. Explain that a round (four Event cards) should be completed before moving on to the next round. Emphasize that the point total in each column is carried over to the next round (see sample answer for Handout 5.2-1 for an example of this). As groups are playing the game, walk around and check that each student is entering a brief description of each event in the appropriate column. This will help students during the analysis part of the activity.

**Follow-Up**

4. **Discuss the patterns shown by the scores from the game.** (15 minutes)

   a. Use the Analysis questions to discuss the results of the game.

   When discussing Analysis question 1, remind students that they learned about ecosystem services in Chapter 4. The pattern described in Analysis question 3 should be evident to students no matter which Event Cards they used during the simulation. Use the question to generate a short discussion of reasons for the pattern, i.e. why there might be negative environmental effects when there are positive economic and social events such as building schools, resorts, factories, and roads. At
Activity 5.2

this stage do not go too deeply into the discussion as this relationship will be revisited in the next activity. This discussion foreshadows the introduction of trade-offs in the next activity.

b. Discuss whether students were able to improve their area by the end of the game.

Analysis question 5 can be used to foreshadow the concept of criteria, which is formally introduced in the next activity. In some cases students will find it difficult to state whether their area was in a better condition at the end of the game than at the beginning, since some point totals may have decreased while others increased. Point out that if the group had previously agreed on a way to measure success then it would be easier to determine if their area had been improved. At this stage do not use the term “criteria” but emphasize that identifying and specifying desired conditions in advance would have provided a way to gauge success.

5. Revisit the Guiding Question. (5 minutes)

a. Revisit the guiding question “How can we balance human needs with those of the environment?” before concluding the activity. Ask students how difficult it was to balance the needs of humans (housing, schools, roads, energy, recreation, etc.) with protecting the environment. Ask students to reflect on whether their decisions tended to favor addressing human or environmental needs. Use the language of the disciplinary core ideas (ESS3.C) and the crosscutting concepts (stability and change, cause and effect, and CET&S) as you facilitate the discussion. In the next activity, students will begin to formally evaluate solutions from environmental, economic, and social perspectives. They will do so after being introduced to the importance of setting criteria and working within constraints.

Suggested Answers To Analysis

NOTE: Analysis questions marked with (Assessment) are suggested opportunities to check for student understanding. Hints for using the questions are included with the suggested answers.

1. List the ecosystem services that your group discussed during the activity?

Assessment – DCI - MS-LS4.D
This question provides an opportunity to learn more about students’ understanding of ecosystem services.
Student responses will vary depending on the Event Cards that they used. Likely responses include: farming, hunting, fishing, energy, and recreation. If necessary, remind students of places where they have encountered the concept of ecosystem services previously in the unit.

2. **Describe an example of a cause and effect relationship that occurred during the game.**

   **Assessment – CCC - Cause & Effect**
   
   This question provides an opportunity to assess students’ understanding of the crosscutting concept of cause and effect in relation to the actions that they took (or declined to take) during the early part of the game and the consequences (effects) that occurred during the latter parts of the game.

   There are numerous examples that students could describe. They could use examples from the events on individual cards, such as building a large farm near the river reduced the environmental points of the river and gulf areas. They could also use examples that had long term consequences, such as deciding not to build the dam in Round 1 leading to an increased loss of environmental, money, and happiness points during the flooding event in Round 3.

3. **Describe any patterns that you saw between the environmental, money, and happiness points.**

   Student responses will vary but the main pattern will likely be that actions which increased the money and happiness points frequently decreased the environmental points. Students might suggest that there is a cause and effect relationship between human action and impact on the environment. Help students to see that the impact is often negative unless engineered otherwise.

4. **Explain how an event in one area could affect another area.**

   **Assessment – DCI – ESS3.C; CCC – Cause and Effect, Stability & Change, and Connections to Engineering, Technology, and Applications of Science**

   This question provides an opportunity for students to show their understanding of the crosscutting concepts of stability and change and cause and effect in the context of ESS3.C (Typically as human populations...increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.)

   Student responses will vary depending on the examples that they choose. There are many examples where an event in one environmental area affected one or more other areas. These include events along the river that also affect the gulf. This will happen since the river feeds into the gulf. Events in the lake can also affect the river and gulf, since the lake is connected to the river. Other effects might be a little less obvious such as building schools, roads, or new housing. These will benefit people from several areas although the environmental impacts might be felt only in the immediate area. Students may point out that a small change in one area may cause a large change later.
Activity 5.2

5. Do you believe that your area was in a better condition at the end of the game than at the beginning? Explain the reasoning behind your answer.

Students’ responses will vary depending on their scores. Check the reasoning behind their answer. Some students may consider that their area has improved if they finished with a higher point total than they started with. Other students may have increased the total number of points but the points may be high in two categories (such as economic and social) and low in one (such as environmental). In such a case they may decide that the decrease in the one category outweighed the increase in the other categories and therefore the condition of their area had worsened.

More Information

Group Work

This unit assumes that students work in pairs and small groups (usually four students) to engage in the practices of science. You may wish to explain your expectations for working together as group and emphasize the role of collaboration in science and engineering. If you wish to model productive group interactions (both agreement and constructive disagreement), the Group Interaction Student Sheet 1, “Developing Communication Skills,” provides sentence starters you can model and students can use to facilitate discussion. This Student Sheet is in the Teacher Resources section.
Activity 5.2

Explore: Stability and Change

Materials and Advance Preparation

For each group of four students

- 1 set of 6 Round 1 event cards*
- 1 set of 5 Round 2 event cards*
- 1 set of 4 Round 3 event cards*
- 1 map

* Note that each group needs four Event cards for each Round. Six Round 1 cards and five Round 2 cards have been provided. This allows for some differences in experiences between groups. Shuffle (or have students shuffle) each set of Event cards before use.

For each student

- Handout 5.2-1, “Score Sheet”

** You may want to prepare a second set of Handout 5.2-1, “Score Sheet” for each class. They will use one sheet during the practice and will likely need a fresh sheet for the actual game.

Teaching Suggestions

1. Discuss ways in which humans impact the environment. (15 minutes)
   a. Ask the class to describe examples from previous chapters where humans have had an impact on the environment.
   b. Confirm that human actions often have consequences for the environment.
   c. Introduce the game.

Doing the Activity

2. Students learn the rules of the game in a practice round. (20 to 25 minutes)
   a. Organize students into groups of four.
   b. Distribute the map and Handout 5.2-1, “Score Sheet.”
c. Explain how to use the Event cards and the scoring system.

d. Direct students’ attention to Process and Procedure Step 4.

e. Allow groups time to play a practice round.

3. **Groups complete playing three rounds of the game.** (30 to 40 minutes)

**Follow-Up**

4. **Discuss the patterns shown by the scores from the game.** (15 minutes)
   
   a. (Assessment) Use the Analysis questions to discuss the results of the game.
   
   b. Discuss whether students were able to improve their area by the end of the game.

5. **Revisit the Guiding Question.** (5 minutes)
Designing a Solution

What factors should be considered when choosing, or designing, a solution to an environmental problem?

Students revisit the previous two activities as they analyze the impacts of decisions made in terms of the effects on the environment, people, and communities. They learn that solutions are designed to operate within constraints and that criteria are used to develop or choose the optimal solution. Finally, they apply criteria and constraints as they use a framework to evaluate potential solutions to the crop infestation problem from an environmental, economic, and social perspective.

Rationale & NGSS Integration

In the two prior activities in this chapter, students saw that every course of action has consequences. They saw that the consequences could be short- or long-term, intended or unintended, and included impacts on humans and the environment. In this Explain activity, students are formally introduced to a framework where they consider the environmental, economic, and social impacts of decisions or proposed courses of action. Students are also introduced to the concepts of criteria and constraints as applied to designing or evaluating a solution. Through their analysis of potential solutions to an environmental problem, students see that decisions that society takes are not solely based on scientific knowledge.

Activity Overview

In this Explain activity, students design a solution to the crop infestation problem by evaluating how well various courses of action meet designated criteria and constraints, and how each affects environmental, economic, and social considerations. In doing so, students realize that solutions to environmental problems often involve trade-offs and that decisions are influenced by more than scientific considerations.
Activity 5.3

Key Vocabulary

criteria (criterion)  constraints
economic   social

Materials and Advance Preparation

For the teacher

☐ 1 set of 6 Round 1 event cards (from Activity 5.2)
☐ 1 set of 5 Round 2 event cards (from Activity 5.2)
☐ 1 set of 4 Round 3 event cards (from Activity 5.2)

For each group of four students

☐ 1 set of 2 Insect Solution cards

For each student

☐ 1 Handout 5.3-1, “Analyzing the Insect Solutions”
☐ 1 Handout 5.3-2, “Designing Solutions”

Teaching Summary

Getting Started

1. Discuss decisions made in the previous activity.

Doing the Activity

2. Students complete the reading.
3. Groups complete and discuss Handout 5.3-1.
4. (Assessment) Students apply criteria and constraints to evaluate the insect solutions.
5. (Assessment) Groups design a solution using Handout 5.3-2.
Follow-Up

6. Review criteria and constraints.

7. Revisit the Guiding Question.

References


Teaching Suggestions

Getting Started

1. Discuss decisions made in the previous activity. (5 to 10 minutes)

   a. Use the Event Cards from Activity 2 to begin a conversation about the consequences of decisions.

      Read aloud an Event Card from Round 1 or 2 of the game from Activity 2 and ask the class to recall what consequences there were from the decisions they made relating to that event. Repeat this procedure using another card. Ask students if the consequences affected people or the environment. Student responses should typically indicate that both were affected.

   b. Ask students to recall situations where decisions had unintended consequences.

      Ask the class to provide examples of decisions from the game where there were unintended consequences, such as deciding not to dam the river and later suffering from flooding. Follow up this discussion by calling on students to describe situations that they have experienced or heard about where there were unintended consequences of decisions.
Activity 5.3

Doing the Activity

2. **Students complete the reading.** (10 to 15 minutes)
   
   a. Assist students with the reading as necessary.
      
      Draw students’ attention to the words in bold type. If you used symbols to represent “money” and “happiness” in the previous activity, use the same symbols with “economic” and “social” so that students can connect these terms across the activities. Explain that “economic” and “social” are broader terms than “money” or “happiness”, using examples from the reading to support your explanation.

   b. Introduce the concepts of criteria and constraints.
      
      Review the reading and use familiar examples to help students understand the difference between criteria and constraints. For example, the criteria for choosing a new cell phone might include that it has a fast processor and a good camera, whereas constraints might include it costing less than $150 and at least an 8 MP camera. Another example might be choosing a backpack for school. Constraints may include cost and size. Criteria may include quality of build, durability, number of pockets, range of colors, style, etc. Add the terms criteria and constraints to the Word Wall.

   c. Discuss how the best solutions address environmental, economic, and social needs.
      
      Use the Venn diagram to illustrate how some solutions might address just one or two needs (environmental, economic, and/or social) by asking students to point to the relevant sections of the diagram as you describe the area(s) of need met. Point out that the intersection of all three circles represents where all three areas of need are met and that this would be indicative of a good solution. Ask the class if they think it is always possible to develop a solution that addresses all three areas of need. See the More Information section for additional detail about Venn Diagrams.

3. **Groups complete and discuss Handout 5.3-1.** (25 minutes)
   
   a. Assist groups in completing their row of the handout.
      
      Distribute Handout 5.3-1 and assign groups to one of the four solutions from Activity 1. Make sure that at least one group is assigned to each solution. Provide five to ten minutes for groups to discuss and record how their assigned solution pertains to environmental, economic, and social considerations. Student responses on the handout provide a quick way of checking how well students have understood the distinction between environmental, economic, and social considerations.
b. Organize groups for sharing the impact of their solution.

Have groups meet with another group that was assigned the same problem to compare their responses. Allow each pair of groups to report out to the class. Students should listen to the group reports and record information for the other rows of the handout. When all the rows have been completed, discuss with the class which solution had the smallest economic impact, which had the smallest social impact, and which had the least environmental impact. Students should realize that no one solution had the smallest impact in all three categories. A sample completed handout 5.3-1 is provided in the Handouts section of the Teacher Guide.

This is a suitable place to end day 1 of this activity.

4. Students apply criteria and constraints to evaluate the insect solutions.
(10 to 15 minutes)

<table>
<thead>
<tr>
<th>Assessment – DCI – MS-ETS1.B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process and Procedure Steps 6 to 9 provide an opportunity to assess how well students have understood the concepts of criteria and constraints.</td>
</tr>
</tbody>
</table>

a. Hand out the Insect Solution cards.

There are two cards (labelled A and B) for each group of four students. One pair of students in the group should examine Card A, while the other pair examines Card B.

b. Assist students as needed in choosing the best solution for their card.

Cards A and B contain different sets of criteria and constraints. For each card, the constraint will eliminate one of the four solutions. The constraint on Card A will eliminate the Relocation option. The constraint on Card B will eliminate the Chemical Control option.

The criteria should narrow the choices down further. For Card A, students are likely to select the Chemical Control option as best meeting the criteria. For Card B, students might choose Biological Control as the best match. Some variation in choice of solutions is possible depending on how students interpret some of the information about each solution.

c. Instruct students to share their choice of solution within the group.

Have the pair of students with Card A share their choice of solution and their reasons for making that choice. Repeat the process with the pair of students with Card B.
d. Ask the class to share how the different criteria and constraints affected their choice of solution.

Use student responses to emphasize how the design or choice of a solution is greatly influenced by the criteria and constraints that are applied.

5. **Groups design a solution using Handout 5.3-2.** (20 minutes)

Assessment – DCI – MS-ETS1.B; SEP – Constructing Explanations and Designing Solutions

Process and Procedure Steps 10 to 12 provides an opportunity to assess how well students can design a solution to an environmental problem. Step 10 also provides an opportunity for assessment of ELA Common Core State Standard WHST6-8.1

a. Explain how to use Handout 5.3-2.

Remind students of the discussion in Activity 1, where the problem and the needs of the solution were identified. Guide the class to enter information from that discussion into boxes 1 and 2 of handout 5.3-2.

b. Tell the class that each group will use the handout to design a solution to the insect problem.

Inform groups that they will need to decide on 1 constraint and at least 2 criteria to apply to the design of their solution to the insect problem. They should enter the constraint information into box 3 and the criteria into box 4. Encourage groups to choose criteria related to at least two sections of the Venn diagram in the student book (environmental, economic, and social.) If students are having difficulty deciding on criteria, consider making a decision through a class discussion.

c. Guide groups in filling out section 5 of the handout.

Tell groups that they can use a previous solution, combine solutions, or come up with a new solution of their own. After groups have completed section 5 of the handout, ask students if there are any disadvantages associated with their solution. If necessary, refer students back to the disadvantages that they identified on Handout 5.1-1 in Activity 5.1 and remind them of any negative consequences of decisions made in Activity 5.2.

d. Introduce the concept of a trade-off.

Explain that trade-offs involve giving up something that is a benefit or an advantage in exchange for something that may be more desirable. Provide examples of trade-offs, 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. In requesting the paper bag, though, they are contributing to other environmental problems, such as increased water and energy use, and the higher amounts of solid waste and carbon dioxide emissions associated with making paper bags. Neither choice is ideal, and both choices have a downside. Identifying the trade-offs helps clarify the reasoning that is being applied to make a decision.

e. Facilitate a class discussion about the best solution.

Discuss competing criteria and any changes that the class may want to make to the criteria or constraints. After some discussion encourage the class to use section 6 of the handout to come up with a better solution. Make sure that students provide their reasoning for why the new solution is better than the previous one.

Follow-Up

6. Review criteria and constraints. (5 minutes)

a. Use Analysis items 1 and 2 in a discussion of criteria and constraints.

Students should note that human-related criteria can often be in opposition to environmentally related criteria.

b. Use Analysis item 3 in a discussion of the role of science in making decisions.

Help students understand that scientific knowledge can describe the consequences of actions but does not necessarily determine the decisions that society takes. Be ready with some local or regional examples (for example, development/preservation issues) in case students struggle to come up with their own.

7. Revisit the Guiding Question. (5 minutes)

a. Revisit the guiding question “What factors should be considered when choosing, or designing, a solution to an environmental problem?” before concluding the activity. Students should be able to explain that one way to examine solutions to environmental problems is by considering the environmental, economic, and social impacts. They should also be able to explain how criteria and constraints guide a solution and that sometimes criteria can conflict, in which case the solution will likely
Activity 5.3

involve some degree of trade-offs. As you facilitate the discussion, use the language of the disciplinary core ideas (ESS3.C, ETS1.B) and the crosscutting concepts (Influence of Science, Engineering, and Technology on Society and the Natural World – All human activity draws on natural resources and has both short- and long-term consequences, positive and negative, for the health of people and the natural environment. The uses of technologies, and limitations on their use, are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions).

Suggested Answers To Analysis

NOTE: Analysis questions marked with (Assessment) are suggested opportunities to check for student understanding. Hints for using the questions are included with the suggested answers.

1. **How do criteria and constraints affect the development of a solution?**

   **Assessment – DCI – MS-ETS1.B**
   This question provides an opportunity to learn more about students’ understanding of the role of criteria and constraints in developing solutions.

   Criteria describe the desired features of a solution. Constraints are limits that apply to solving the problem. As a solution is developed, efforts are made to meet the criteria and stay within the limits of the constraints.

2. **Which types of criteria were often in competition with one another?**
   Suggest reasons why.

   **Assessment – DCI – ETS1.B; CCC- Influence of Science, Engineering, and Technology on Society and the Natural World**
   This question provides an opportunity to assess understanding of the difficulties of satisfying competing criteria.

   Student answers will vary. A sample answer is shown below.

   Environmental criteria were often competing with economic and social criteria. For example, physical removal of the insects will help preserve the environment but will cost a lot of money and people may lose their jobs, at least for a while. This is because reducing human impact on the environment requires people to take action and/or apply suitable technologies.
3. **Scientific knowledge is valuable when making decisions because it can describe the consequences of actions. However, science is not usually the only consideration when making a decision. Explain why, using an example from a problem that has affected your own community.**

**Assessment – DCI– MS-ESS3.C: CCC-Connections to the Nature of Science**

This question provides an opportunity to assess student understanding of the concept of human impact on the environment and that scientific knowledge can describe the consequences of actions but does not necessarily prescribe the decisions that society takes.

Student answers will vary. A sample answer is shown below.

Decisions that affect the environment usually affect people and decisions that affect people often affect the environment. So the decisions need to be made by considering both the environmental impact and the impact on people and communities. A few years ago the school district built a new bus garage on land that was made available by filling in part of a wetland area next to a school. This decision reduced the total area of wetland by almost 50%. Although this affected the habitat of many organisms it was felt that the need for the new bus garage was important to the community. The school district felt that by keeping some of the wetland area the environmental effects would be small.

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**More Information**

**Sustainability**

Although the term “sustainability” is not used in this unit, the general concepts introduced in Chapter 5 pertain to sustainable development. In 1987, the United Nations World Commission on Environment and Development (WCED) reported, “Humanity has the ability to make development sustainable – to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs.” There are three generally accepted dimensions to sustainability: environmental, economic, and social. In the student book, they are represented as a Venn diagram with sustainability being at the intersection of all three circles. An alternative visual utilizes concentric circles with the economy circle inside the society circle, which is inside the environment circle. This is helpful in showing that the economy and society are constrained by environmental limits.
Venn Diagrams

A Venn diagram includes two or more overlapping circles in which words or phrases are written to help visually depict the similarities and differences between two or more things, concepts or categories. Each circle is labeled according to the subjects being compared. Students write information that is unique to the subject of each circle in the outer part of the appropriate circle. In the overlapping space they write the information or elements common to both subjects. A Venn diagram allows students to visually map characteristics that are both unique and shared among a set of concepts or things. The diagram is flexible and easily adjusted by adding additional circles to compare up to four ideas.
Activity 5.3

*Explain: Designing a Solution*

**Materials and Advance Preparation**

**For the teacher**
- 1 set of 6 Round 1 event cards
- 1 set of 5 Round 2 event cards
- 1 set of 4 Round 3 event cards

**For each group of four students**
- 1 set of 2 Insect Solution cards

**For each student**
- 1 Handout 5.3-1, “Analyzing the Insect Solutions”
- 1 Handout 5.3-2, “Designing Solutions”

**Teaching Suggestions**

**Getting Started**

1. **Discuss decisions made in the previous activity.** (5 to 10 minutes)
   a. Use the Event Cards from Activity 2 to begin a conversation about the consequences of decisions.
   b. Ask students to recall situations where decisions had unintended consequences.

**Doing the Activity**

2. **Students complete the reading.** (10 to 15 minutes)
   a. Assist students with the reading as necessary.
   b. Introduce the concepts of criteria and constraints.
   c. Discuss how the best solutions address environmental, economic, and social needs.
3. **Groups complete and discuss Handout 5.3-1.** (25 minutes)
   a. Assist groups in completing their row of the handout.
   b. Organize groups for sharing the impact of their solution.

4. **Students apply criteria and constraints to the insect solutions.** (10 to 15 minutes)
   a. Hand out Insect Solution cards.
   b. Assist students as needed in choosing the best solution for their card.
   c. Instruct students to share their choice of solution within the group.
   d. Ask the class to share how different criteria and constraints affected their choice of solution.

5. **Groups design a solution using Handout 5.3-2.** (20 minutes)
   a. Explain how to use Handout 5.3-2.
   b. Tell the class that each group will use the handout to design a solution to the insect problem.
   c. Guide groups in filling out section 5 of the handout.
   d. Introduce the concept of a trade-off.
   e. Facilitate a class discussion about the best solution.

**Follow-Up**

6. **(Assessment) Review criteria and constraints.** (5 minutes)
   a. Use Analysis items 1 and 2 in a discussion of criteria and constraints.
   b. Use Analysis item 3 in a discussion of the role of science in making decisions.

7. **Revisit the Guiding Question.** (5 minutes)
Evaluating Solutions

How can we evaluate solutions to decide how well they might work?

In the previous activity, students were introduced to a system that could be used in designing and evaluating solutions. In this Elaborate activity they apply the system to potential solutions for real world environmental problems. They develop and use environmental, economic, and social criteria to choose the best combination of solutions that fall within the limits of identified constraints. They complete the activity by suggesting refinements to their solutions.

Rationale & NGSS Integration

In this activity students apply the framework used in the previous activity to evaluate solutions to an assigned environmental problem. Students interact with the core ideas of human activities impacting the environment in both positive and negative ways, increasing human populations typically causing negative environmental impacts, and that there are systematic processes for evaluating solutions. They engage in the science and engineering practice of (constructing explanations and) designing solutions as they develop criteria before evaluating and refining solutions to complex real world problems. In doing so, students prioritize criteria and consider trade-offs. They also engage with the crosscutting concepts of cause and effect, stability and change, and connections to the nature of science as they see firsthand how developing solutions to environmental problems involves more than scientific considerations.

Activity Overview

In this Elaborate activity groups are assigned a current environmental problem. They brainstorm solutions and develop a criterion-based system which they use to rank their solutions from best to worst. Groups then use the same system to
evaluate several solutions to their assigned problem. They suggest a solution to the problem, which may be a combination of previously examined solutions.

Key Vocabulary

biodiversity  ecosystem services

Materials and Advance Preparation

For each group of four students

☐ 1 Handout 5.4-1, “Possible Solutions”

For each student

☐ 1 Handout 5.3-2, “Designing Solutions” (blank copy, from Activity 5.3, optional)

Teaching Summary

Getting Started

1. Discuss environmental disruptions previously encountered in the unit.

Doing the Activity

2. (Assessment) Groups brainstorm solutions to a specific environmental problem and develop criteria applicable to the solutions.

3. (Assessment) Groups apply their criteria to a list of possible solutions before choosing a combination of solutions and designing their own.

Follow-Up

4. (Assessment) Revisit the Guiding Question.
Teaching Suggestions

Getting Started

1. Discuss environmental disruptions previously encountered in the unit.
   (10 to 15 minutes)
   
   a. Ask the class to describe the types of environmental disruptions that they have encountered in the unit so far.

   Delve deeper into a few of the disruptions to see if the class can identify the causes and effects of each one. For example, hunting wolves to extinction reduced biodiversity and affected the food web, and the introduction of an invasive species (zebra mussels) altered the food web, changed the clarity of the water, and affected ecosystem services.

   b. Read the Introduction to the class.

As needed, refer to the Word Wall and remind students of the meaning of terms such as biodiversity and ecosystem services. Tell the class that in this activity they are going to examine several current environmental problems and evaluate potential solutions to them before choosing a combination of the solutions and then refining them.

Doing the Activity

2. Groups brainstorm solutions to a specific environmental problem and develop criteria applicable to the solutions. (30 minutes)
   
   a. Assign one of the four environmental problems to each group.

   If possible, have at least two groups assigned to each problem as they will compare their thinking at various points during the activity. Allow time for students to read about their assigned problem. Provide assistance in understanding the readings as needed.

   b. Have groups identify cause and effect for their assigned problem.

Assessment – DCI– MS-ESS3.C; CCC- Stability and Change, Cause and Effect

Process and Procedure Step 2 provides an opportunity to check for understanding of the crosscutting concepts of cause and effect and stability and change and human impact on Earth systems as groups write down the cause of the problem and describe its effects.
A sample answer is provided below.

**Environmental Problem 1**

- **Cause:** Overfishing of predators of crown-of-thorn starfish.
- **Effects:** Increase in number of crown-of-thorn starfish. Increase in damage to coral reefs.

**Environmental Problem 2**

- **Cause:** Villagers using the protected area to hunt animals and expand their farms.
- **Effects:** Decrease in biodiversity of the forest. Increase in soil erosion. Increase in sediment in the lake producing reduction in water quality and changes to the food web of the lake.

**Environmental Problem 3**

- **Cause:** Invasive species (zebra mussel) in states near to Yellowstone Lake.
- **Effects:** None yet, but trying to avoid the introduction of the zebra mussel to the lake. This would cause disruptions to the food web and to ecosystem services.

**Environmental Problem 4**

- **Cause:** Destruction of habitat, overfishing, and increased runoff into Chesapeake Bay.
- **Effects:** Reduction in water quality of the bay. Large decrease in oyster populations. Increase in dead zones.

c. Have each group agree on the constraints and criteria that they wish to apply to a solution to their environmental problem.

Provide some time for groups to first brainstorm constraints and criteria that they wish to apply to a solution to their problem. Then have them brainstorm possible solutions before using the criteria to rank their solutions from best to worst. Bring groups together who are studying the same problem and allow them to compare their solutions, rankings, constraints and criteria.

This is a good place to end day 1 of this activity.
3. **Groups apply their criteria to a list of possible solutions before choosing a combination of solutions and designing their own.** (30 to 35 minutes)

   a. Distribute Handout 5.4-1, “Possible Solutions” to each group.

   Allow time for the groups to discuss the positive and negative effects of the possible solutions for their assigned problem. Encourage groups to separate the possible effects of each solution into environmental, economic, and social impacts. An example of a possible response for the solutions for Environmental Problem 1 is provided below.

**Sample Student Response to Environmental Problem 1**

<table>
<thead>
<tr>
<th>Solution</th>
<th>Environmental Impact</th>
<th>Economic Impact</th>
<th>Social Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Poison in starfish might get into other organisms.</td>
<td>Will provide employment for divers.</td>
<td>People may not be happy with a poison being used where they live.</td>
</tr>
<tr>
<td>B</td>
<td>Will probably allow the area to recover.</td>
<td>Will reduce employment for fishermen but might increase tourism.</td>
<td>Some people will see the protected area as a good thing. Families of fishermen may have to leave the area.</td>
</tr>
<tr>
<td>C</td>
<td>Doesn’t solve the problem.</td>
<td>No effect.</td>
<td>Some people may feel they are making a useful contribution to solving the problem.</td>
</tr>
<tr>
<td>D</td>
<td>Could become an invasive species and affect the food web.</td>
<td>Unknown effect depending on how the food web is affected.</td>
<td>People might not want a non-native fish in the area.</td>
</tr>
<tr>
<td>E</td>
<td>Will allow the area to recover some.</td>
<td>Will provide employment for fishermen.</td>
<td>The families of fishermen would likely be able to stay as there is more work.</td>
</tr>
</tbody>
</table>
Activity 5.4

b. Distribute Handout 5.3-2, “Designing Solutions” to each student.

Groups should fill out the front side of the Handout. Tell the class to add one constraint for the final solution for each environmental problem—a maximum budget of $500,000. Allow time for groups to make adjustments to their criteria (if they wish) and to make sure that they have at least one criterion related to each category—environmental, economic, and social. Note: some criteria may apply to more than one category.

c. Help students to complete Handout 5.3-2, “Designing Solutions” for their assigned environmental problem.


Step 8 is aligned to the practice of Engaging in Argument from Evidence, specifically to evaluating competing design solutions based on jointly developed and agreed-upon design criteria. Step 9 ties to the practice of Constructing Explanations and Designing Solutions, specifically to applying scientific principles to design an object, tool, process, or system.

Assist groups as necessary as they decide on a solution. Most groups will choose a combination of solutions. There is no single correct answer to each problem. Look for logic in each group’s reasoning and use of criteria and constraints. The solutions that groups propose will likely weigh one category of criteria more than another and thus will involve trade-offs. Section 6 of the handout provides an opportunity for students to refine their solutions.

d. Allow groups to share their solutions.

Have groups share with the other group(s) studying the same problem. Then provide time for each pair of groups to report out to the class.

Follow-Up

4. Revisit the Guiding Question. (10 to 15 minutes)

a. Use a whole class discussion to summarize the processes that groups used in developing criteria and designing solutions.

Use Analysis questions 1 and 2 as part of the discussion.

b. Revisit the Guiding Question.

As you revisit the guiding question, “How can we evaluate solutions to decide how well they might work?” remind students of the process that
they used to evaluate their assigned solution. Once again emphasize
the need to use a systematic approach and to use criteria that include
the environmental, economic, and social considerations. As in the
previous activity, point out that all solutions have to operate within a set
of constraints. These constraints may be economic (for example, not
enough money to carry out all of the actions), temporal (actions have
to happen within a certain time span, etc.), environmental (for example,
certain land areas or species must be protected), etc.

c. Use Analysis question 3 to discuss the role of human needs and values in
designing solutions to environmental problems.

Use the language of the disciplinary core ideas (ESS3.C), the science
and engineering practices (Constructing Explanations and Designing
Solutions), and the crosscutting concepts (Cause and Effect) as you
discuss Analysis question 3. In the discussion bring up the nature of
science crosscutting concept (Connections to the Nature of Science)
“scientific knowledge can describe the consequences of actions but
does not necessarily prescribe the decisions that society takes.” Ask
students to describe whether this concept applies to their solutions. Tell
the class that in the final activity, groups will design a method to stop or
reduce a threat to coral reefs. To do so they will apply the system that
they used in this activity.

Suggested Answers To Analysis

NOTE: Analysis questions marked with (Assessment) are suggested opportunities
to check for student understanding. Hints for using the questions are included with
the suggested answers.

1. Describe how your criteria were similar to that of the other group who had
the same environmental problem.

Assessment – DCI – MS-ETS1.B
This question provides an opportunity to assess understanding of the need for a
systematic process for evaluating solutions that takes into account criteria and
constraints.

Answers will vary but students should note that the criteria used to evaluate
all of the solutions were related to environmental, economic, and social
considerations.
2. **Describe how your criteria were different from that of the other group who had the same environmental problem.**

   **Assessment – DCI – MS-ETS1.B**
   This question provides an opportunity to assess understanding of the need for a systematic process for evaluating solutions that takes into account criteria and constraints.

   *Answers will vary. Some groups may have prioritized criteria differently than other groups, discounted some criteria, or added additional criteria.*

3. **Can environmental problems be solved by technology alone? Explain your answer.**

   **Assessment – CCC – Connections to Engineering, Technology, and Applications of Science; Connections to the Nature of Science.**
   This question provides an opportunity to assess understanding of the role that individual or societal needs, desires, and values play in formulating solutions.

   *Student responses will vary. Look for logical reasoning in the response. In particular, look to see if students understand that although technology can play a big role in solving problems, it also requires humans to understand the problems and solutions and for policies and procedures to be put in place and to be followed. Thus, although scientific knowledge can describe the consequences of actions, it does not necessarily prescribe the decisions that society takes.*
Activity 5.4

_Elaborate:_ Evaluating Solutions

Materials and Advance Preparation

For each group of four students

- 1 Handout 5.4-1, “Possible Solutions”

For each student

- 1 Handout 5.3-2, “Designing Solutions”

Teaching Suggestions

Getting Started

1. **Discuss environmental disruptions previously encountered in the unit.** *(10 to 15 minutes)*
   
   a. Ask the class to describe the types of environmental disruptions that they have encountered in the unit so far.
   
   b. Read the Introduction to the class.

Doing the Activity

2. **(Assessment) Groups brainstorm solutions to a specific environmental problem and develop criteria applicable to the solutions.** *(30 minutes)*
   
   a. Assign one of the four environmental problems to each group.
   
   b. Have groups identify cause and effect for their assigned problem.
   
   c. Have each group agree on the constraints and criteria that they wish to apply to a solution to their environmental problem.

3. **(Assessment) Groups apply their criteria to a list of possible solutions before choosing a combination of solutions and designing their own.** *(30 to 35 minutes)*
   
   a. Distribute Handout 5.4-1, “Possible Solutions” to each group.
   
   b. Distribute Handout 5.3-2, “Designing Solutions” to each student.
c. Help students to complete Handout 5.3-2, “Designing Solutions” for their assigned environmental problem.

d. Allow groups to share their solutions.

Follow-Up

4. (Assessment) Revisit the Guiding Question. (10 to 15 minutes)

a. Use a whole class discussion to summarize the processes that groups used in developing criteria and designing solutions.

b. Revisit the Guiding Question.

c. Use Analysis question 3 to discuss the role of human needs and values in designing solutions to environmental problems.
Coral Reefs

How can the negative impact of humans on coral reefs be reduced?

Students are introduced to a broad range of threats to coral reefs around the world. They draw upon their understanding of designing solutions as groups develop and present a solution to one of the threats. As part of their presentation, groups make an argument for why their solution is a good response to minimizing human impact on the reef. After the presentations the class evaluates how well the solutions meet the specified criteria and constraints and how the threat illustrates how increases in human populations and resource use negatively impact the environment.

Rationale & NGSS Integration

In this activity students apply what they have learned in this chapter and in the unit to develop a solution to minimize human impact on coral reefs. With minimal guidance they use a systematic approach to first developing and later evaluating solutions. As has been the case throughout this chapter students interact with the core ideas of human activities impacting the environment in both positive and negative ways, increasing human populations typically causing negative environmental impacts, and that there are systematic processes for evaluating solutions. They apply the practice of argumentation and engage with the crosscutting concepts of stability and change, and cause and effect. Finally, they demonstrate an understanding of the nature of science as they acknowledge that solutions, especially to global problems, are often influenced by factors other than science.
Activity Overview

In this Evaluate activity groups choose a threat to the health of coral reefs that is caused by humans. They design a solution to reduce or minimize the threat and present it to the class. They evaluate each of the solutions presented and construct an argument for the one that is most effective and sustainable.

Key Vocabulary
biodiversity  ecosystem services

Materials and Advance Preparation

For each student

☐ 1 Handout 5.3-2, “Designing Solutions” (optional)

Teaching Summary

Getting Started

1. Facilitate a class discussion about coral reefs.

Doing the Activity

2. Groups complete the reading on threats to coral reefs using a literacy strategy.

3. Groups choose and summarize a threat.

4. (Assessment) Groups use a systematic approach to design a sustainable solution to stop or reduce the threat.

Follow-Up

5. (Assessment) Groups present their solutions to the class.

6. Revisit the Guiding Question.
Teaching Suggestions

Getting Started

1. Facilitate a class discussion about coral reefs. (10 minutes)
   a. Remind the class about the environmental problems they studied in the previous activity.

   Draw the attention of the class to Environmental Problem 1 in the previous activity, the issue of overfishing of predators of the crown-of-thorn sea star and the consequent damage done to coral reefs by an overabundance of these starfish. Use the introduction to this activity to provide more detail about coral reefs, emphasizing both their fragility and importance in marine ecosystems.

Doing the Activity

2. Groups complete the reading on threats to coral reefs using a literacy strategy. (15 minutes)
   a. Assist students as needed with the coral reef reading.

   If necessary, review the “Read, Think, and Take Note” literacy strategy with the class. After groups have finished reading, ask them to share some of the notes that they wrote. Use these notes to frame a summary of the reading, writing the various threats on a board or chart paper. The main problems identified in the reading are: fishing - overfishing and destructive fishing techniques; pollution – including excess nutrients and increased sediments; tourism – direct damage from physical contact, indirect damage from pollution and development. If needed, clarify the difference between food and nutrients since nutrients are mentioned at the end of the reading. The effects of climate change, such as increasing ocean temperatures and acidity are mentioned in the reading. These should be included in the list of threats but steer groups away from choosing these problems since they have not been considered previously in the unit and are extremely complex. This may be a topic students could investigate over the course of the year.

3. Groups choose and summarize a threat. (10 minutes)
   a. Allow time for groups to choose a threat.

   Some of the threats will be more familiar to students than others (e.g.: overfishing). Circulate among the groups and discuss why they chose
**Activity 5.5**

that particular threat. As you do so, check for understanding. You might want to remind the class about the importance of using systematic processes as they develop and evaluate solutions.

**b.** Have students write a summary of the threat they have chosen.

Step 3 of the procedure asks groups to write a paragraph to summarize the threat. Group responses will vary depending on the threat that they chose. A sample response is shown below:

*The threat that my group has chosen is the effect of overfishing on the coral reef. Many organisms live in and around coral reefs. This makes them attractive places for catching fish. When one or more species are overfished there will be disruptions to the food web. Some species will likely decrease while others will increase. When a species like the crown-of-thorns sea star increases, it can cause damage to the coral reef. Coral reefs are important for their biodiversity and for the ecosystem services that they provide. They only make up a small fraction of the ocean floor. Over a quarter of the world’s coral reefs have been destroyed over the last 50 years. Therefore it is important to protect the coral reefs that remain.*

This is a suitable place to end day 1 of this activity.

**4. Groups use a systematic approach to design a solution to stop or reduce the threat.** (40 minutes)

**a.** Remind students of the steps they have used in designing and evaluating solutions.

**Assessment – PE– MS-ESS3-2**

Step 4 asks groups to design a method to stop or reduce the threat. This is related to Performance Expectation MS-ESS3-3, “Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.”

Remind students of Steps 1 to 4 on Handout 5.3-2.

1. Describe the problem.
   (Already done in Process and Procedure Step 3)
2. Describe the needs that the solution is to address.
3. Identify the constraints that the solution must meet.
4. Identify the criteria that apply to the solution.

Point out that this time they are not provided with solutions to choose from or to adapt. Groups will have to design their own solutions that best meet the criteria and constraints.
Check to see if groups addressed the required aspects of the solution and that they used a systematic process. A sample response is provided below:

The threat is overfishing at coral reefs. This has caused a change in the food web and reductions in the number of fish remaining. The average size of fish caught has also decreased.

Our solution is designed to protect the biodiversity of the reef, keep the food web in balance, but still provide employment for fishermen and food and income for their families.

The constraints for our solution are a) that no organisms be added to the coral reef ecosystem, and b) families of fishermen will not have to leave the area.

The criteria that we will use are:
1. The number of fish should increase as close to the previous numbers (before the overfishing began) as possible. (Environmental)
2. The biodiversity of the reef shall be maintained as best as possible. (Environmental)
3. Ecosystem services will be maintained as best as possible. (Social and Economic)
4. The income of local families should be negatively affected as little as possible. (Social and Economic)

Our solution would be to set fishing limits for all species found in and around the reef and to employ fishermen to monitor the number, types, and sizes of fish.

The fishing limits would be set each year and would include limits on the number and sizes of organisms caught. The number would depend on the stability of the populations of the reef. If a population became unstable due to low numbers, we may have to set the fishing limit to zero until that population recovered.

The reasoning behind our solution relates to the crosscutting concepts of stability and change and cause and effect. In order to keep the coral reef ecosystem stable it is important to minimize disruptions to the food web. Overfishing a predator, prey, or producer could cause a large disruption to the reef. Our solution meets the environmental criteria because it would prevent the removal of any part of the food web and restore balance to the ecosystem.

Our solution also works from an economic and social perspective. Since fishing will still be allowed (unless a population’s numbers becomes too low), fishermen will still be able to earn a living. Although fewer fish may
be caught, in the long term it will help sustain the fishery. The fishermen could also be employed to monitor the health of the coral reef.

Our solution falls within the constraints as the ecosystem will recover naturally when the overfishing is stopped and therefore there is no need to add fish or other organisms to increase the numbers. It is also unlikely that fishermen’s families would have to move. This is because fishing would still be allowed, so they would still have a source of income. Also, there would be new job opportunities because people would be hired to monitor the recovery of the reef and to check that the fishing limits were being followed.

Evidence that would indicate our solution was working would come from environmental, economic, and social sources. In particular we would want to see no reduction in the size of the healthy reef and no reduction in the number and types of species found there. We would expect to see the number of organisms increase and the size of the fish caught should also increase. We would want to see no decrease in ecosystem services, such as tourism. We would not want local families to lose any income because of the fishing restrictions. There should be no families who are forced to move away from the area due to lack of jobs or money. Ideally, we would want to see an increase in the standard of living for families of those who make a living from the reef.

This is a suitable place to end day 2 of this activity.

Follow-Up

5. **Groups present their solutions to the class.** (40 minutes)

**Assessment – PE– MS-LS2-5 and ESS3-4**

Step 6 provides an opportunity for students to address a blend of Performance Expectations MS-LS2-5 (“Evaluate competing design solutions for maintaining biodiversity and ecosystem services”) and MS-ESS3-4 (“Construct an argument supported by evidence for how increases in human population impact earth’s systems.”) Although Step 6 suggests an oral argument, if a written response was submitted it could be assessed against WHST6-8.1.

a. Explain that Step 6 represents the culminating assessment for the chapter.

Before each group presents their solution to the class, remind students that the various solutions are to be evaluated against the criteria and constraints. If necessary, remind students that the criteria will address environmental, economic, and social needs and that trade-offs should be described.
b. Remind students of the process of scientific argumentation.

Students are not required to submit a written response to Step 6, but look for students’ ability to construct an oral argument. Review the process of argumentation as needed. Encourage students to include the effect of increasing human population in their response. Although empirical data may not be available students could reference the evidence that groups identify in the last bullet point in Step 4. A sample response is provided below:

The question that I am arguing is which of the presented solutions is best at reducing human impact on the coral reef. My claim is that the solution that involved setting limits and monitoring fishing in and around the reefs will minimize human impact. The evidence that would support my claim is that in this solution there would be no reduction in the area of the reef and the number and types of organisms found there. There would also be no reduction in income for people who fish there. This means that the solution meets the environmental, economic, and social criteria and constraints.

My reasoning is based on knowing that the best solution is one that meets environmental, economic, and social needs. This solution meets environmental needs because it would help to maintain the stability of the food web of the reef. It will help keep the balance of predators, prey, and producers. The solution also meets economic and social needs because it will not require any fishermen to lose their jobs. As the human population increases, there is extra stress on the reef. This is because there will be more demand for fish and probably more tourists visiting the reef. Even though there will be limits on some types of fishing, the fishery will be healthier in the long run which should help to provide stability with fishing jobs and a steady supply of fish. There is also the possibility for the fishermen to earn extra income by helping to monitor the health of the reef. They could monitor the number and types of organisms on the reef. They could also watch for people using destructive fishing techniques, like using explosives. By keeping the reef healthy, the money from increased tourism can help the families in the area. By helping to maintain income and jobs, families will feel more stable and secure. I did not choose any of the other solutions because I thought that they mainly addressed the environmental aspects of sustainability. Although they may have helped the reef, they would have caused problems with jobs and the stability of families who made a living from the reef.
c. Allow groups to present their solutions to the class.

Where possible, groups should use presentation software, posters, or other tools to enhance the presentations. Draw students’ attention to Process and Procedure Step 6 and encourage members of the class to provide feedback on each solution and presentation. Provide time for groups to revise their solutions based on feedback from the class.

6. **Revisit the guiding question.** (10 minutes)

a. Use the Guiding Question as a focus for a discussion on human impact on the environment.

Begin the discussion by focusing on human impact on coral reefs. Expand the discussion to include examples of human impact seen throughout the unit. Conclude the discussion by encouraging students to share other examples of human impact that they have encountered or heard of. Remind students to use the language of the disciplinary core ideas (ESS3.C) and the crosscutting concepts (stability and change and cause and effect) as they state opinions and positions.

b. Use Analysis question 1 to relate the discussion to the nature of science.

Students have already encountered the concept that “scientific knowledge can describe the consequences of actions but does not necessarily prescribe the decisions that society takes.” They should understand that solving environmental problems that are caused by human actions is difficult. From discussion of this question they should realize that it becomes even more difficult when multiple communities and countries are involved.

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**Suggested Answers To Analysis**

1. Some of the causes of threats to the health of coral reefs are local and some are global. How does the challenge of designing and applying a sustainable solution differ when the cause is a worldwide problem, such as climate change?

*Science can describe the consequences of actions but society does not always take decisions based on science alone. A sustainable solution has to address economic and social needs too. With a global threat the needs of many people and communities would have to be considered. There are many differences between communities and also between countries. These include money available, needs, politics, values, and many others. A global solution would need the agreement and action of all countries. This would be very difficult to achieve.*
Activity 5.5

Evaluate: Coral Reefs

Materials and Advance Preparation

For each student

- 1 Handout 5.3-2, “Designing Solutions” (optional)

Teaching Suggestions

Getting Started

1. Facilitate a class discussion about coral reefs. (10 minutes)
   a. Remind the class about the environmental problems they studied in the previous activity.

Doing the Activity

2. Groups complete the reading on threats to coral reefs using a literacy strategy. (15 minutes)
   a. Assist students as needed with the coral reef reading.

3. Groups choose and summarize a threat. (10 minutes)
   a. Allow time for groups to choose a threat.
   b. Have students write a summary of the threat they have chosen.

4. (Assessment) Groups use a systematic approach to design a solution to stop or reduce the threat. (40 minutes)
   a. Remind students of the steps they have used in designing and evaluating solutions.
Follow-Up

5. **(Assessment) Groups present their solutions to the class.** (40 minutes)
   a. Explain that Step 6 represents the culminating assessment for the chapter.
   b. Remind students of the process of scientific argumentation.
   c. Allow groups to present their solutions to the class.

6. **Revisit the guiding question.** (10 minutes)
   a. Use the Guiding Question as a focus for a discussion on human impact on the environment.
   b. Use Analysis question 1 to relate the discussion to the nature of science.