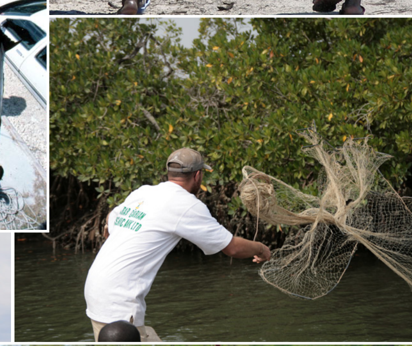
# ECOLOGY

## Unit Issue

**THROUGHOUT THE WORLD, PEOPLE, COMMUNITIES,** and countries rely on natural resources for many uses, including food. The ways that people use these resources can affect their sustainability. Fish and other seafood are important natural resources that are a source of food for many people throughout the world. Approximately 3 billion people, 40% of the world's population, rely on seafood as a major source of protein, and roughly 10% of the world's population depend on commercial fisheries for their livelihood. A **fishery** is an industry that catches or raises a specific type of fish or shellfish to be processed or sold. Commercial fisheries throughout the world are valued at over $400 billion a year. Fisheries also include *recreational fishing* (fishing for fun or for competition), which contributed over $39 billion to the United States GDP in 2019.

**FIGURE A:** *Fisheries are an important source of income and food throughout the world.*

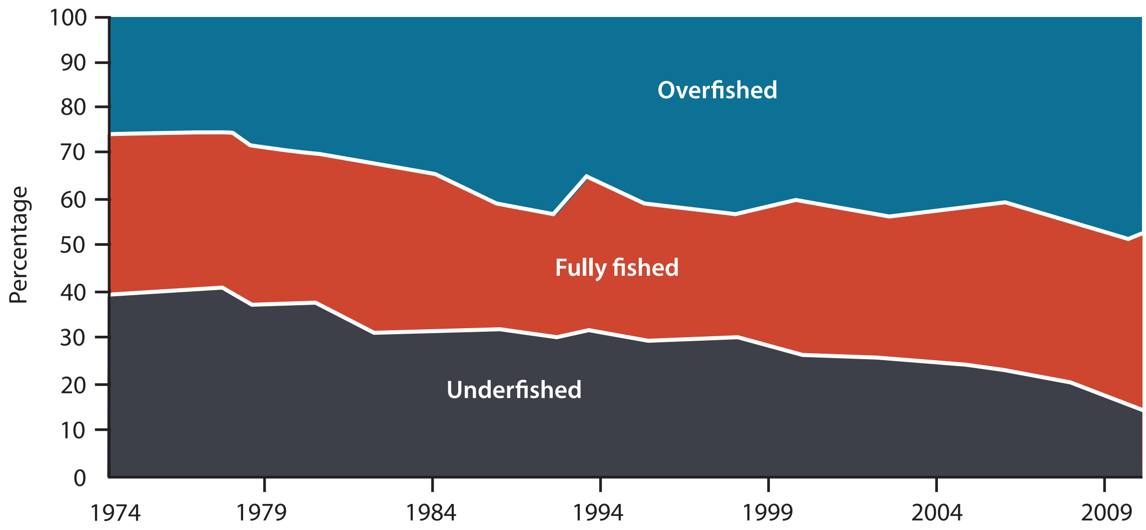


The sustainability of fisheries—whether for personal consumption, income, or recreation—is critical to the livelihoods and nutrition of billions of people. It is important that fisheries stakeholders work together to determine what it means for a fishery to be sustainable. Would it matter to you if a fish species, like salmon, could no longer be fished? What kinds of information and data are needed to manage a fishery sustainably?

The graph in Figure B shows wild saltwater *fish stocks* (populations that are harvested by people) over time. What do you observe about the data, and what can you infer? What questions does this graph generate?

In this unit, you will explore the issue of *sustainable fisheries* as an example of how humans both rely and have an impact on natural resources. You will analyze and interpret data on factors that affect the abundance and distribution of different populations of organisms. You will use mathematical reasoning and models to help you find patterns of stability and change in ecosystems. You will explore the flow of energy and the cycling of matter in ecosystems, and how disruptions to these processes affect ecosystems at different scales. You will explore the impact of humans on ecosystems and evaluate plans to minimize negative effects. Ultimately, you will develop a plan for making a commercial fishery more sustainable.

**FIGURE B:** *Sustainability of fisheries over time*



# 4 Scaling Up: Ecosystems

## Investigative Phenomenon

In the previous learning sequence, you explored individual populations of organisms and factors affecting them. Populations are part of ecosystems that include many kinds of organisms. The song sparrows are part of the Mandarte Island ecosystem, which also includes cowbirds and many other organisms. Coral reefs are another type of ecosystem. Imagine a coral reef in your mind. Which of the photos in Figure 4.1, all of coral reefs, most closely resembles what you imagined? What similarities and differences do you notice among the different reefs? What factors do you think could contribute to these differences? In this learning sequence, you will explore factors that explain some of the differences among ecosystems.

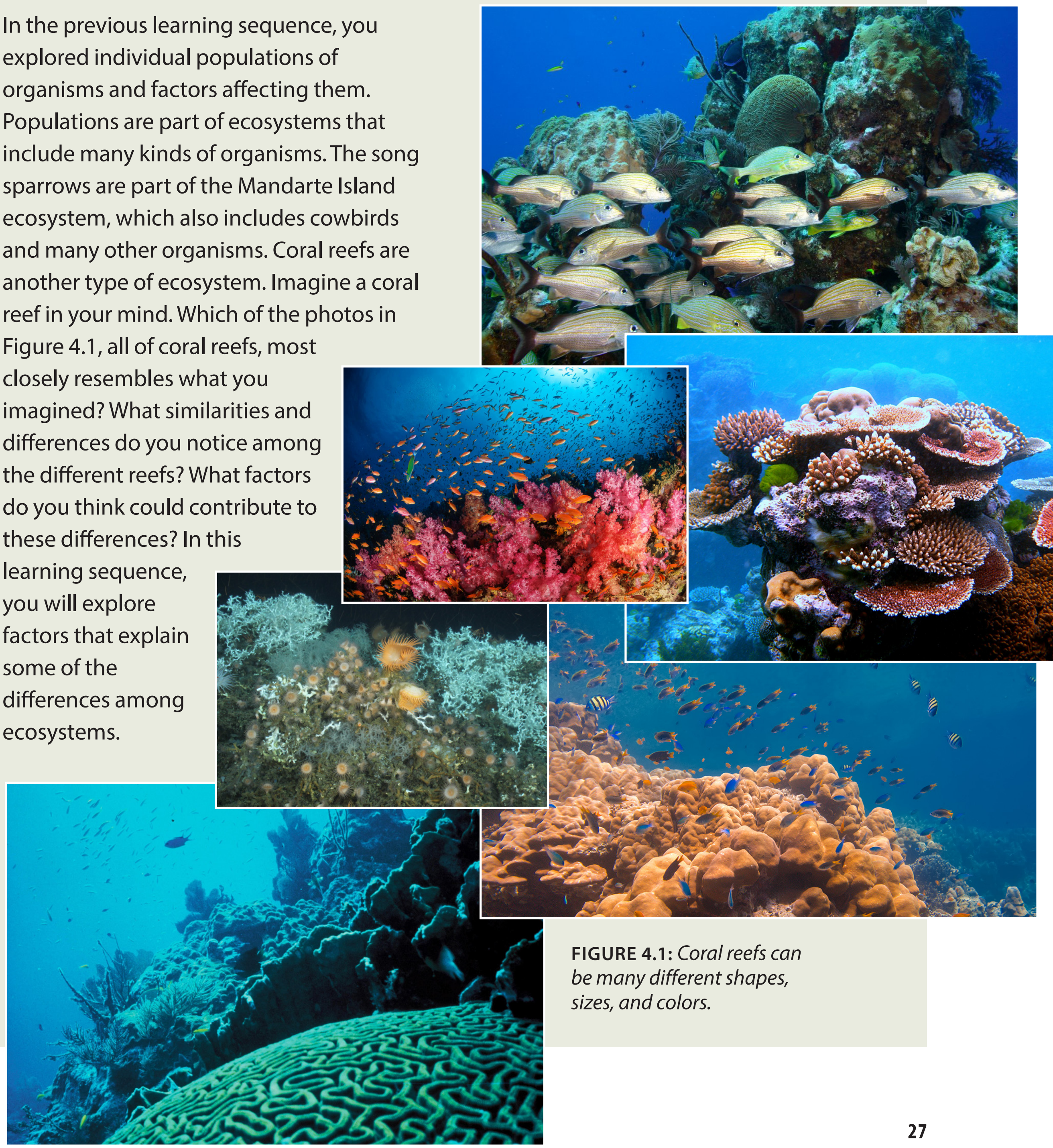


**FIGURE 4.1:** *Coral reefs can be many different shapes, sizes, and colors.*

In the previous activity, you investigated data collected from a bird population on an isolated island. Scientists can define that ecosystem easily: It's the island. But what happens when an ecosystem is not isolated? How can researchers define what that ecosystem is? How can an understanding of an isolated ecosystem be applied to other, less isolated ecosystems? In this activity, you will explore how four different types of ocean ecosystems can be defined.

## Guiding Question

**What defines an ecosystem?**

## Materials

**FOR EACH STUDENT**

Student Sheet 4.1, "Ecosystem Comparisons"

## Procedure

1. Read the following text box about the crosscutting concept of *systems and system models*, and discuss with your partner how you think this concept relates to ecosystems.

> A **system** is an organized group of related components that form a whole.
>
> A **system model** specifies the components within the system and how the components interact with one another. It must also specify the boundary of the system being modeled, defining what is included in the model and what is considered external.

2. Follow your teacher's instructions for determining which of the four ecosystems your group will explore.
3. With your group, read the information about the ecosystem you are investigating. Use Student Sheet 4.1, "Ecosystem Comparisons," to take notes on the following factors for your ecosystem:
   - Components: Abiotic and biotic factors that are important in your ecosystem

- Interactions: Relationships between different components of your ecosystem
- Boundaries: Limits to your ecosystem; how it is divided from other ecosystems
- Scale: The relative size of your ecosystem

## *Ocean Sunlight Zone*

**FIGURE 4.2:** *These fish live in the ocean sunlight zone.*

Oceans cover more than 70% of the earth and contain more than 97% of the earth's water. Scientists divide the ocean into different layers, or zones. The zone above 200 meters in depth is considered the *sunlight zone*. Below this depth, the amount of light drops significantly. The ecosystem occupying the sunlight zone is the most extensive ecosystem on Earth. It begins where the shallow coastal waters surrounding all the continents end, and it extends outward through the rest of the oceans' surfaces. Abiotic conditions, such as light, temperature, salinity, and circulation, in the ocean sunlight zone are fairly consistent at any given location.

Approximately 10%–15% of the known species on Earth are found in the sunlight zone, but this accounts for 90% of all *marine* (ocean) life. Many unique types of organisms in the ocean are not found on land. In fact, the ocean is more diverse than land with regard to major groups of organisms. Several groups of animals are found only in the ocean, including sea stars (starfish), sea urchins and their relatives, comb jellies, acorn worms, and trumpet worms. Other animals in the ocean include extremely large species, such as whales and sharks, and many smaller vertebrate species, including fish, sea birds, and sea turtles. The majority of marine fisheries rely on fish that live in the sunlight zone.

Invertebrates account for over 95% of the animal species found in the ocean. These include crustaceans (shrimps, crabs, etc.), mollusks (clams, octopuses, etc.), and sea jellies (jellyfish). The sunlight zone is also home to tiny organisms called *plankton*, which are carried along ocean currents. One drop of ocean water can contain hundreds of these organisms, most of which are too small to see with the naked eye.

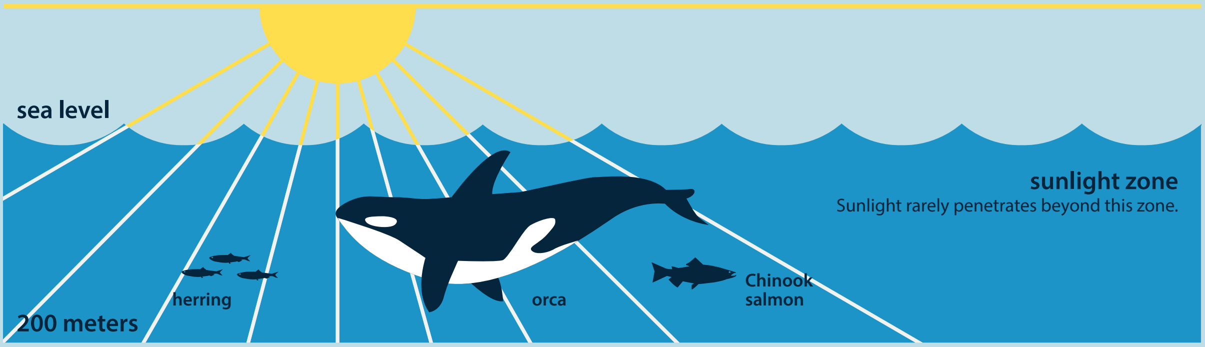



**FIGURE 4.3:** *The ocean sunlight zone refers to the top 200 m of the ocean.*

## *Coral Reefs*

Coral reefs occupy less than 0.1% of the ocean's area, about 285,000 km$^2$, yet they are home to over 25% of all marine species. Because of the tremendous diversity of life found on reefs, they are sometimes called the "rainforests of the ocean." Coral reefs tend to be found in relatively shallow, warm water in the tropics, at latitudes between the Tropic of Capricorn and Tropic of Cancer. However, some coral species have evolved to live in deeper, colder water.

Coral reefs get their name from the organisms that form the physical foundation for the coral reef ecosystem. *Reef-building corals* are tiny colonial animals that produce a hard outer skeleton of limestone. This skeleton attaches to either rock or the dead skeletons of corals, building up the reef structure over time. Many coral colonies can live for hundreds or thousands of years. Most reef-building corals have algae living in their tissues. The corals and algae have a *mutualistic relationship*: The coral provides the algae with a protected environment, and in return the algae produce oxygen and nutrients that the coral can use for its own needs. This relationship, which evolved millions of years ago, has allowed coral to live in nutrient-poor water.

Coral reefs are one of the most diverse ecosystems in the world. In addition to the nearly 1,000 species of hard coral that form the reefs, the reefs are home to tens of thousands of other species, including hundreds of soft corals; invertebrates, such as sea cucumbers, anemones, sponges, jellies, and octopuses; and vertebrates, such as sea turtles and sea snakes. Reefs also provide food, safety, and spawning areas for at least 4,000 different species of fish.

**FIGURE 4.4:** *Many organisms live in and among coral reefs.*

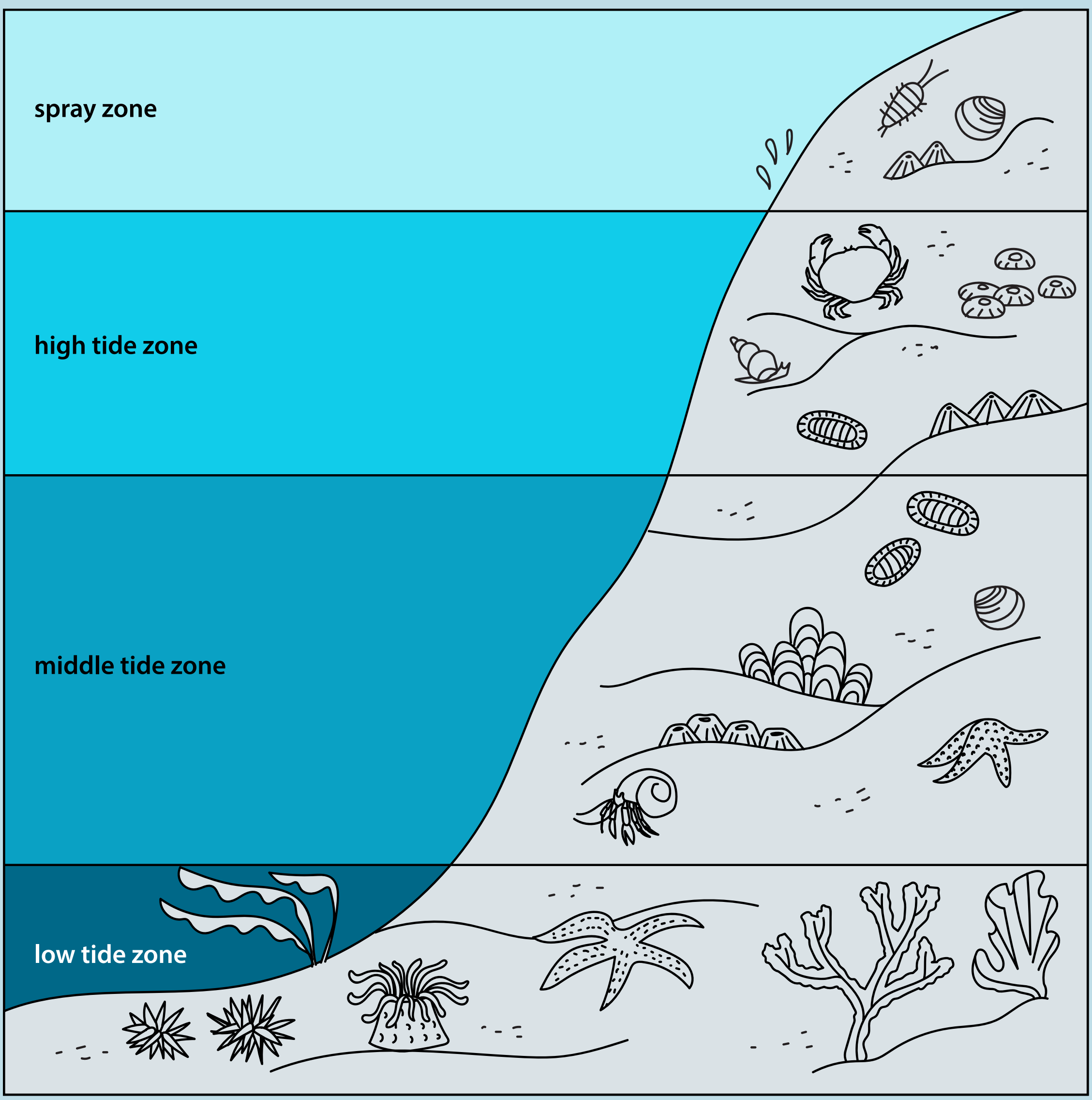
**FIGURE 4.5:** *Coral reefs are made of the hard outer skeleton of individual coral polyps.*

## *Intertidal Zone*

All marine shorelines around the world experience tides. The *intertidal zone* is the area of the shoreline that is exposed to air at low tide and covered with seawater at high tide. Some intertidal zones are rocky and may have shallow pools of water remaining in depressions in the rocks during low tide. Others are sandy, with no standing water during low tide. Intertidal zones can be divided into sub-zones depending on how long the sub-zone is exposed to air; the upper sub-zone is the area exposed for the longest period of time. Some intertidal zones are large, stretching for hundreds of meters from the shore, while others are isolated and narrow and extend less than a meter from shore.

All the organisms that inhabit the intertidal zone are marine species who have adapted to living in this continually changing environment.

**FIGURE 4.6:** *The tidal zone is subdivided into several zones, depending on how long the zone is exposed to air when the tide is out.*



## *Intertidal Zone continued*

The algae that live here have adapted to being exposed to air or being underwater for long periods of time. Many kinds of invertebrates are found in this zone. Barnacles are often found in the upper part of the zone (with the greatest exposure to air). Sea stars are typically found in the lower part of the zone, which is usually submerged in water. Organisms found in the middle of the zone include mussels, crabs, and anemones.

Twice a day at low tide, intertidal organisms may be exposed to air for many hours. They may also experience large changes in other abiotic factors, such as temperature and sunlight. Most intertidal animals feed only when in water. Many also use oxygen dissolved in water rather than from air. Thus, they are at risk of starvation and suffocation during low tide. Animals living permanently in the intertidal zone have evolved a variety of adaptations that enable them to survive in this challenging habitat.

At low tide, intertidal organisms are exposed to predation by land animals (such as gulls). At the same time, low tide allows them to escape predation by marine animals that cannot survive in the intertidal zone (such as fish), or by animals that can't live in the upper part of the intertidal zone (such as sea stars).

**FIGURE 4.7:** *This rocky tide pool contains many organisms, including ochre sea stars and sea anemones.*

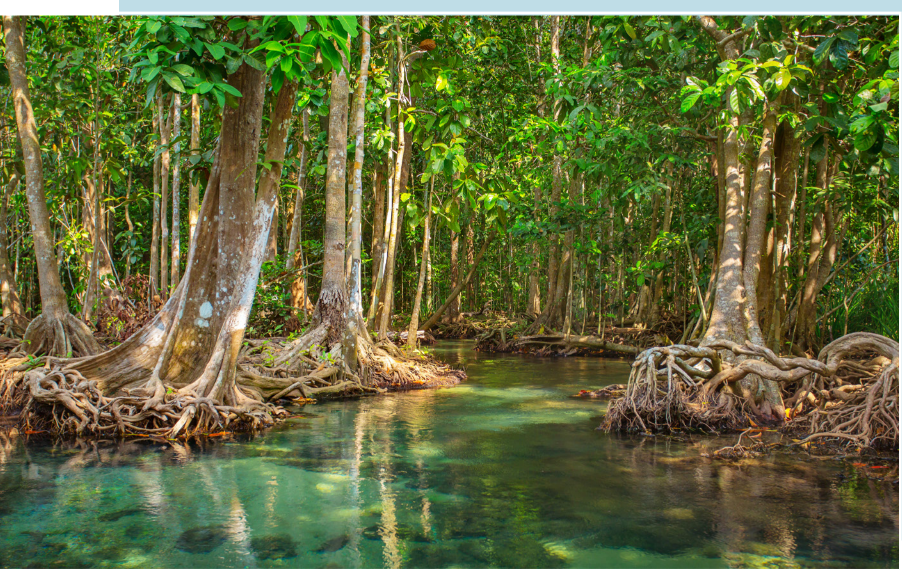


**FIGURE 4.8:** *Mangrove forests grow in the intertidal zones near the equator.*

## *Humpback Whale Respiratory Microbiome*

Humpback whales are large marine mammals found in oceans and seas around the world. Like all whales, humpbacks have adapted to living in water, yet rely on breathing air to get oxygen and expel carbon dioxide. Whales don't have noses like most mammals; instead, they have a blowhole on the top of their heads that connects to their lungs. Humpbacks breathe through this blowhole when the top of their head breaks through the surface of the water. The blowhole is kept closed by muscles when the humpback is under water. When a humpback exhales air out of its blowhole, a spray can often be seen. This spray is a mixture of seawater and the exhaled contents of the humpback's lungs.

Scientists have known for years that whales' respiratory systems are a common site for bacterial infections. But only recently, by studying the spray from humpbacks' blowholes, did scientists discover that many species of bacteria and other microbes live in the respiratory system of healthy whales. In fact, a core group of bacteria can be found in the respiratory system of healthy whales who live in different oceans. This core group of bacteria is a *microbiome*, a specific group of microorganisms found in a particular environment—in this case, the whale's respiratory system. Similar to the *human gut microbiome* (the group of microorganisms found in your stomach and digestive tract), each whale's microbiome is unique to the individual whale, depending on many factors. Which microorganisms are present can indicate the health of the whale, and scientists believe that the microbiome may play an important role in fighting off infections and otherwise maintaining the whale's overall health.

Scientists are only beginning to investigate the importance of the humpback's respiratory microbiome, but one thing is becoming clear: Humpback whales may be 16 meters long, but they still benefit from providing a home for their microscopic hitchhikers!

**FIGURE 4.9:** *Many organisms, including humans and humpbacks, rely on microorganisms to maintain their health.*

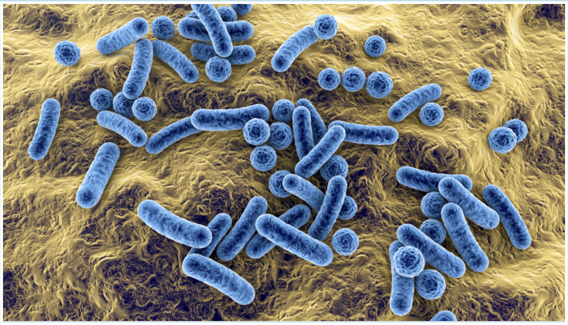


**FIGURE 4.10:** *As humpback whales surface to breathe, they expel a spray. Scientists have studied the contents of this spray and learned that humpback respiratory systems contain complex microbiomes.*

4. Follow your teacher's instructions for sharing information about your ecosystem with your class.

5. In your science notebook, sketch a model for one of the four ecosystems from this activity. Include the ecosystem components (biotic and abiotic), interactions, and boundaries in your model. Be sure to clearly label everything.

6. With your group, return to the information on the crosscutting concept of *systems and system* models in Step 1. Using this information, create a definition of an *ecosystem*. Be prepared to share your definition with your class.

7. Follow your teacher's instructions to come to a consensus as a class on the definition of an *ecosystem*.

## Build Understanding

1. Why is it necessary for researchers to specify the boundary of the ecosystem they are investigating?

2. Suppose you were a scientist developing a model for the Mandarte Island ecosystem and the song sparrows. Would it be easier to identify the components, interactions, and boundaries of this ecosystem than others? Why or why not? What challenges might you have?

3. **Issue connection:** How could understanding the components, interactions, and boundaries of a fishery's ecosystem help scientists monitor the sustainability of that fishery?

4. Figure 4.11 shows are three images taken of the same coral reef at different scales. Explain what types of factors researchers might investigate if they want to monitor the carrying capacity of the reef ecosystem at the scale shown in the photo on the left (a), in the middle (b), and on the right (c).

   *Hint:* Consider what types of components and interactions might be studied at these three scales.

**FIGURE 4.11:** *a. Reef seen from a distance. b. Reef with several species of coral and other organisms. c. Individual coral polyps that make up the coral reef.*

a b c

5. Look again at the coral reef photos at the start of this activity. What might explain the similarities and differences you observed in these coral reefs?

## Extension: Engineering Connection

Studying large ocean animals such as whales poses a lot of challenges. Studying the spray from when they exhale might seem impossible, but a group of researchers developed a very clever method to study the spray of humpback whales. Scientists used small drones to follow the whales and then fly over them as they surfaced, capturing the whale's spray with a special device attached to the drone. The analysis of samples collected using this method led to the discovery of the whales' respiratory microbiome.

Visit the *SEPUP SGI Third Edition* page of the SEPUP website at **www.sepuplhs.org/high/sgi-third-edition** to learn more about this study and what the scientists learned from it.

### KEY SCIENTIFIC TERMS

boundary
component
ecosystem
interaction
scale
**system**
**system model**

# 5 Patterns of Biological Diversity

**IN THE LAST ACTIVITY**, you saw that ecosystems can exist on many scales. While ecosystems all have common features, they also have differences. Some ecosystems contain more species than others. Some have more of a particular type of organism. Why do you think these differences occur? Why might it be important for scientists to understand these differences? In this activity, you will explore patterns of species diversity for different groups of organisms on larger scales—globally and across the United States—and you will consider factors that might lead to these patterns.

## Guiding Question

**What patterns of biological diversity occur for different groups of organisms, and what might cause these patterns?**

## Materials

**FOR EACH GROUP OF FOUR STUDENTS**

- Vertebrate Diversity Map
- set of five Abiotic Factor Maps

## Procedure

### Part A: Global Coral Diversity

1. With your group, look at the map of coral diversity in Figure 5.1. Use what you learned about coral reefs in the previous activity to discuss which abiotic factors may help to explain this pattern. Write your explanation in your science notebook, and be prepared to explain your scientific reasoning with the class.

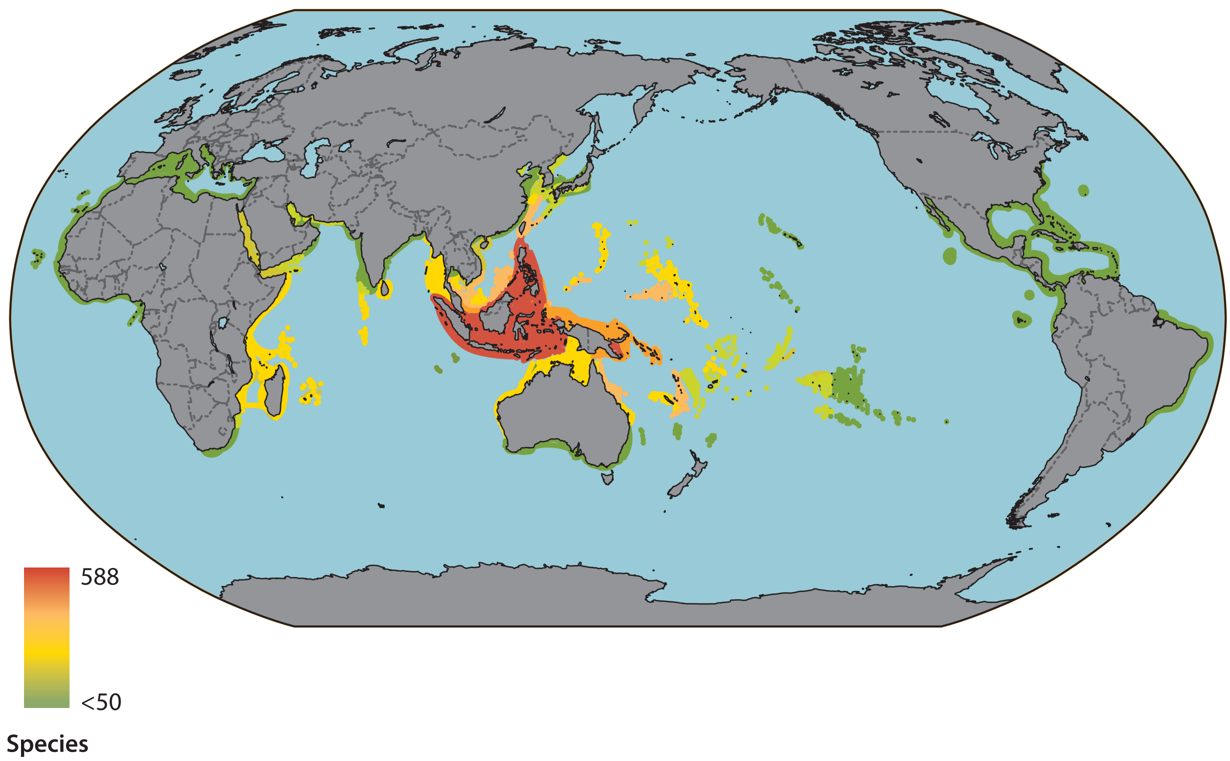



**FIGURE 5.1:** *Global coral diversity*

2. With your group, look at the map of ocean temperature at the surface around the world in Figure 5.2. Discuss how well you think this abiotic factor explains the pattern of coral diversity.

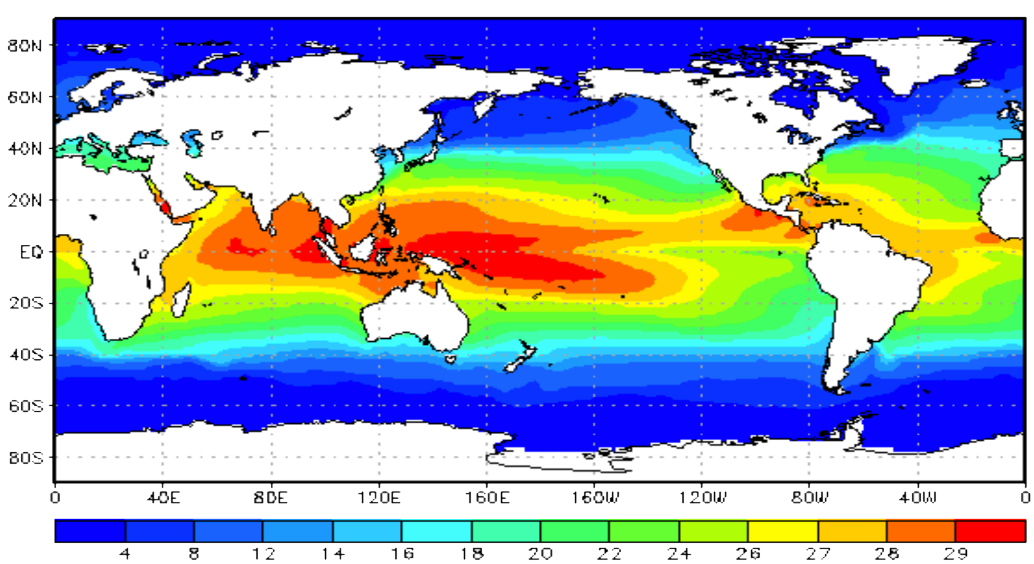



**FIGURE 5.2:** *Ocean surface temperature*

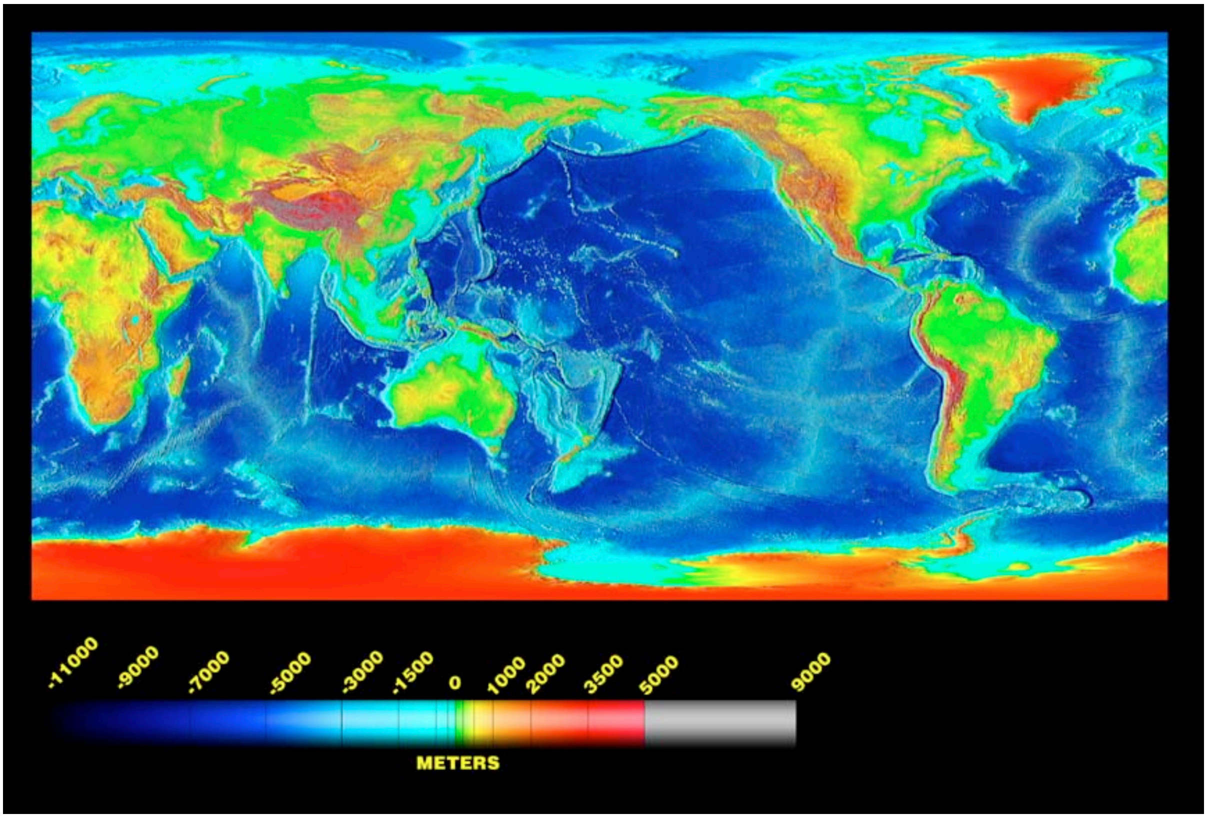



**FIGURE 5.3:** *Ocean depth*

3. Repeat Step 2 for the map of ocean depth in Figure 5.3.

4. Based on your discussions in Steps 2 and 3, revise your explanation in your science notebook from Step 1. Be prepared to share your revised explanation with the class.

## Part B: Vertebrate Groups in the United States

5. Follow your teacher's instructions for determining which groups of vertebrate organisms you will investigate (reptiles, amphibians, birds, or mammals), and obtain the Vertebrate Diversity Map for that group.

6. With your group, read about your vertebrate group and study the map. Where is your vertebrate group most diverse? Where is it least diverse? Based on what you read about your vertebrate group, what ideas do you have about this pattern? In your science notebook, record your initial ideas about what factors might explain the patterns you see in the map.

7. Obtain a set of five Abiotic Factor Maps. With your class, review the Elevation and Topography Map and compare it to the Vertebrate Diversity Map for your organism.

8. Each person in your group should take one of the remaining four Abiotic Factor Maps, study it, and decide whether this factor might be important in explaining the patterns in species diversity for your vertebrate group. Record your ideas in your science notebook.

9. With your group members, take turns sharing information about the factor that you examined. As a group, decide whether each factor might be important in explaining the distribution of your vertebrate group in the United States.

10. Discuss with your group what might account for the patterns you observed, based on all the factors that you considered. Be prepared to share your ideas with the class.

## Build Understanding

1. For the group of vertebrate organisms that you examined:
   a. Write an explanation that can account for the pattern of species distribution. Be sure to discuss all the factors and to use data from the maps to support your explanation.
   b. How did your explanation change as you examined more factors?
   c. Imagine that you were looking at the map for your vertebrate group but on a global scale—like the coral maps you examined. Would you expect to see the same patterns of species distribution in other locations in the world? Why or why not?

2. Select one other vertebrate group that you learned about in the class discussion. Compare and contrast the distribution of that vertebrate group with yours. What might account for any differences in the distribution of the two vertebrate groups?

3. Look again at the coral reef photos at the start of Activity 4: Scaling Up: Ecosystems. Use what you've learned in this activity to explain the differences you see in these photographs.

4. **Issue connection:** Do you think species diversity is important in ecosystems? Is it something that scientists should consider when they are thinking about fisheries' sustainability? Why or why not?

### KEY SCIENTIFIC TERMS

biological diversity

Name________________________________________________ Date__________

## STUDENT SHEET 4.1

### ECOSYSTEM COMPARISONS

| | Ocean Sunlight Zone | Coral Reefs | Intertidal Zone | Humpback Whale Respiratory Microbiome |
|---|---|---|---|---|
| **Components** | ***Biotic*** | ***Biotic*** | ***Biotic*** | ***Biotic*** |
| | ***Abiotic*** | ***Abiotic*** | ***Abiotic*** | ***Abiotic*** |
| **Interactions** | | | | |
| **Boundaries** | | | | |
| **Scale (size comparison)** | | | | |

Name______________________________________________ Date__________

## STUDENT SHEET 5.1

### WRITING FRAME—CONSTRUCTING EXPLANATIONS

I am explaining ____________________________________________________________
____________________________________________________________
____________________________________________________________

The first line of evidence related to my explanation is ______________________________
____________________________________________________________
____________________________________________________________
____________________________________________________________

My reasoning for how and why this evidence leads to my explanation is that ____________
____________________________________________________________
____________________________________________________________
____________________________________________________________

The second line of evidence related to my explanation is _____________________________
____________________________________________________________
____________________________________________________________
____________________________________________________________

My reasoning for how and why this evidence leads to my explanation is that ____________
____________________________________________________________
____________________________________________________________
____________________________________________________________

The third line of evidence related to my explanation is ______________________________
____________________________________________________________
____________________________________________________________
____________________________________________________________

My reasoning for how and why this evidence leads to my explanation is that ____________
____________________________________________________________
____________________________________________________________
____________________________________________________________

In conclusion, ____________________________________________________________
____________________________________________________________
____________________________________________________________

Name________________________________ Date__________

# STUDENT SHEET 5.2

## WRITING REVIEW

Use these questions to review someone else's writing. Answer the following questions after you have read or heard this person's answer *twice*.

Name of the person whose writing you reviewed:

_______________________________________________

State the topic of the writing:

_______________________________________________

_______________________________________________

_______________________________________________

Are the facts clear and accurate? ______________________________

If you answered "no," which facts need to be more clear or need correction?

If you answered "yes," which facts are presented clearly and accurately?

_______________________________________________

_______________________________________________

_______________________________________________

_______________________________________________

Do the facts support the writer's position? ______________________________

If you answered "no," which facts do not support the writer's position?

If you answered "yes," which facts support the writer's position?

_______________________________________________

_______________________________________________

_______________________________________________

List any statements or ideas that the writer did not support with facts.

_______________________________________________

_______________________________________________

Do you agree with the writer's conclusion? Explain why or why not.

_______________________________________________

_______________________________________________

# CONSTRUCTING EXPLANATIONS (EXP)

**When to use this Scoring Guide:**

This Scoring Guide is used when students develop their own explanations of phenomena. Their explanations may be based on evidence from their own investigations, on secondary data sets, and/or on evidence and concepts obtained from text and other media.

**What to look for:**

- Response includes relevant evidence, disciplinary core ideas, and crosscutting concepts.
- Response logically links evidence and concepts to develop a causal mechanism for a phenomenon.

| Level | Description |
|---|---|
| Level 4<br>Complete and correct | The student's explanation<br>• is supported by sufficient use of appropriate evidence and concepts* AND<br>• links the evidence and concepts to provide a clear and complete causal mechanism for the phenomenon. |
| Level 3<br>Almost there | The student's explanation<br>• is supported by sufficient use of appropriate evidence and concepts* BUT<br>• does not clearly link the evidence and concepts to provide a complete causal mechanism for the phenomenon. |
| Level 2<br>On the way | The student's response includes some use of evidence and concepts* relevant to the phenomenon, BUT some key pieces of evidence and/or concepts are missing. |
| Level 1<br>Getting started | The student's response makes little to no use of appropriate evidence and concepts* to develop an explanation for the phenomenon. |
| Level 0 | The student's response is missing, illegible, or irrelevant to the phenomenon. |
| x | The student had no opportunity to respond. |

* *Concepts* may include models, representations, and/or accepted scientific theories