CHAPTER 7

Humans and Global Change

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Flooding in south Florida at high tide

HS-ETS1-2, HS-LS2-2, HS-LS2-7, HS-LS4-6, HS-ESS2-6, HS-ESS3-3, HS-ESS3-4, HS-ESS3-5, HS-ESS3-6, HS-ETS1-1

CASE STUDY

How can a rising tide be stopped?

An octopus thrashing around on the floor of a parking garage? Storm drains that flow backward for a few days every month? Flooded streets during a week of dry, sunny, windless weather? Welcome to southern Florida in the twenty-first century.

Southern Florida—surrounded by the Atlantic Ocean, the Gulf of Florida, and the Gulf of Mexico—has always been tied to the sea. From its "discovery" by European sailors to maritime trade and fishing to the tourist industry, it's hard to imagine the Sunshine State without its beaches and waterways.

But the oceans around Florida are changing. Sea level is rising. Rapidly. Why? Because of changes in Earth systems. As human activity releases greenhouse gases into the atmosphere, the planet warms. Ice in glaciers and on continents like Greenland and Antarctica melts. As ocean water warms, it expands slightly. And climate change affects powerful ocean currents like the Gulf Stream, too, which causes changes in the way tides rise and fall.

The situation might not be serious if Miami and other beach cities in southern Florida had been built on solid rock. But southern Florida is mostly porous limestone, whose consistency geologists compare to Swiss cheese. Florida is also really flat. Most land in and around Miami is less than 2 meters above sea level, and the highest places are only about 4 meters above sea level. Under these conditions, porous limestone and low-lying land make for problems.

Miami Beach has endured frequent ocean flooding of streets, yards, and businesses. Some low-lying areas flood regularly at high tides, while other places flood any time the sun, Earth, and the moon align to produce the highest high tides. Salt water also penetrates through porous limestone to contaminate drinking water. Rising seawater mixes into coastal soil, killing trees and producing "ghost forests."

Facing this threat, Palm Beach, Broward, Miami-Dade, and Monroe counties joined to form the Southeast Florida Climate Compact, whose motto is "Pioneering climate resilience through regional action." Miami Beach has already invested $400 million to build new seawalls, raise street levels, and install powerful drainage pumps. At the time of this writing, those actions seem to be working, but the long-term outlook is still grim.

In some low-lying nations, such as the Netherlands, engineers designed and built dikes and elaborate barriers to close harbors from the open sea when necessary. Those approaches have limited value in Miami, however, because of that limestone "Swiss cheese" beneath the sand. Build a seawall, and sooner or later water will percolate under it.

Is there anything we can do about rising seas? If we can't stop them, can we reduce their harmful effects? What are the most useful actions to take or policies to enact?

Throughout this chapter, look for connections to the CASE STUDY to help you answer these questions.

LESSON 7.1

Ecological Footprints

Chicago, Illinois, population 2.7 million

KEY QUESTIONS

- *How do ecological footprints of typical Americans compare to the global average?*
- *What is the Anthropocene?*

HS-LS2-7: Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

VOCABULARY

ecological footprint
anthrome

READING TOOL

Review Figure 7-1 in your text to determine what makes up an individual's ecological footprint. For each term listed in your **Biology Foundations Workbook,** list two ways you can reduce the impact you make on the planet.

Remember Earth as astronauts saw it, an island of life in the void of space. What they couldn't see is that our planet's human population is climbing toward 9 billion. Our species has triumphed. We've transformed Earth to house and feed ourselves. Yet our success has caused major changes in local and global environments. Human-caused changes in Earth's global systems are affecting Earth's atmosphere, oceans, and climate.

Our Changing Ecological Footprints

How can we wrap our heads around the reality that human activities are affecting global systems? It's hard to conceive of anything powerful enough to change our entire planet. An asteroid impact, maybe. Or a giant solar storm. But people? That's one reason that understanding, controlling, and adapting to human-caused global change are the greatest scientific challenges of this century. The view of global systems and the model of global change we've been building in this unit will help. But to begin, we need to understand how and why each of us as individuals impacts the environment.

Visual Analogy

Figure 7-1

Ecological Footprint

Your ecological footprint includes all of the resources you use.

Ecological Footprints

Let's start with what ecologists call your **ecological footprint**. Your ecological footprint is the total area of healthy land and water ecosystems needed to provide the resources you use. As shown in **Figure 7-1**, ecological footprints include your use of resources such as energy, food, water, and shelter, and your production of wastes, such as sewage, trash, and greenhouse gases.

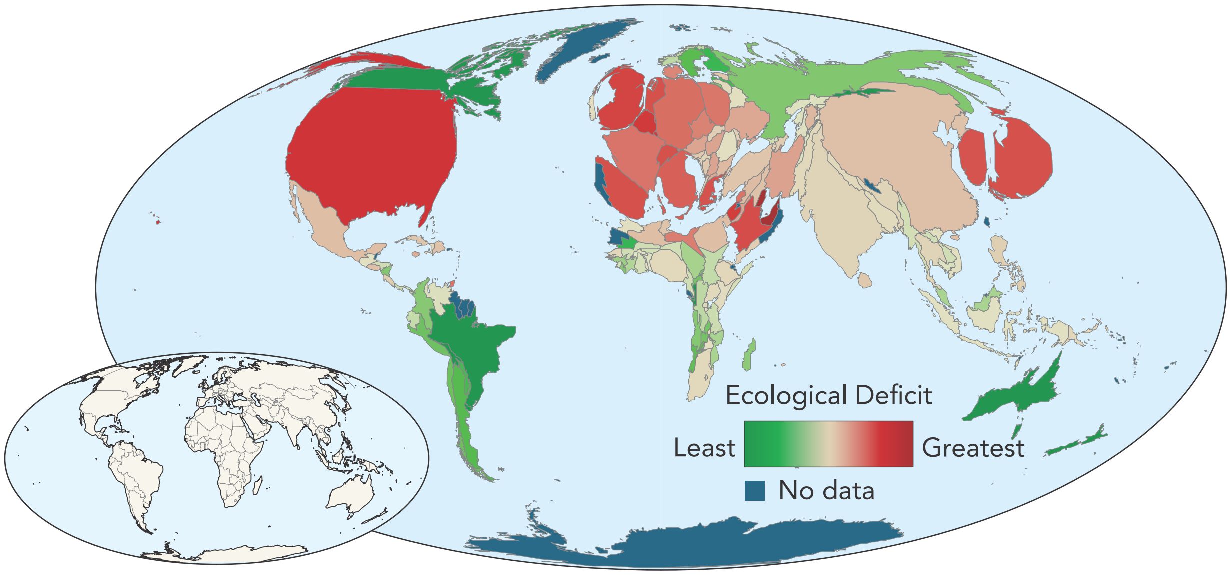


Figure 7-2
National Footprints

The countries in red have ecological footprints that are disproportionately large.

National and Global Ecological Footprints There is no universally accepted formula for calculating ecological footprints. Still, we can make useful comparisons among footprints of people in different countries, as shown in **Figure 7-2**. To determine a country's ecological footprint, researchers calculate the footprint of a typical citizen and multiply that by the size of the population. ***According to some calculations, the average American has an ecological footprint more than four times larger than the global average.*** An average American uses almost twice the resources of an average person in England, more than twice the resources used by an average person in Japan, and almost six times the resources used by an average person in China. Now think, not just about your footprint, but about nearly 9 billion footprints. That incredible amount of human activity drives changes in global systems that affect environments worldwide.

VIDEO
Learn about the origins and activities of Earth Day.

READING CHECK **Describe** What is one way to calculate the ecological footprint of a country?

HS-LS2-7, HS-ETS1-1

Argument-Based Inquiry | Guided Inquiry

Calculating Ecological Footprint

Problem How can you calculate your use of natural resources?

In this lab, you will determine what your ecological footprint is regarding three types of natural resources: water, land, and fossil fuels. Then, you will explore ways to effectively reduce your ecological footprint in one of these areas.

You can find this lab in your digital course.

READING TOOL

As you read, note the order of the global changes caused by human activities.

The Age of Humans

Back in 1969, inventor Buckminster Fuller coined the term "spaceship Earth." Until recently, humans were only passengers on this ship. Although we affected local environments, we had little impact on global systems. But our status as passengers has been changing since the Industrial Revolution of the 1800s. That's when a series of brilliant inventions harnessed fossil fuels to power machinery. Railroads and other forms of transportation connected cities around the globe. Mass production began and spread. And that was just the beginning.

INTERACTIVITY

Investigate the causes and effects of The Great Acceleration.

The Great Acceleration The greatest change in humanity's relationship with Earth began around the 1950s, during a period called "The Great Acceleration." What was accelerating? Just about everything related to people and our impact on global systems, as shown in **Figure 7-3**. We burned more fossil fuels. We farmed more land enriched with fertilizers, and we caught more fish, so we could feed more people. Medical discoveries saved millions of lives. Within a single lifetime, the well-being of millions of people improved dramatically. Death rates fell worldwide. Birth rates stayed high, so the global population grew rapidly. Advancing technology was used by more people, multiplying our impact on local and global systems.

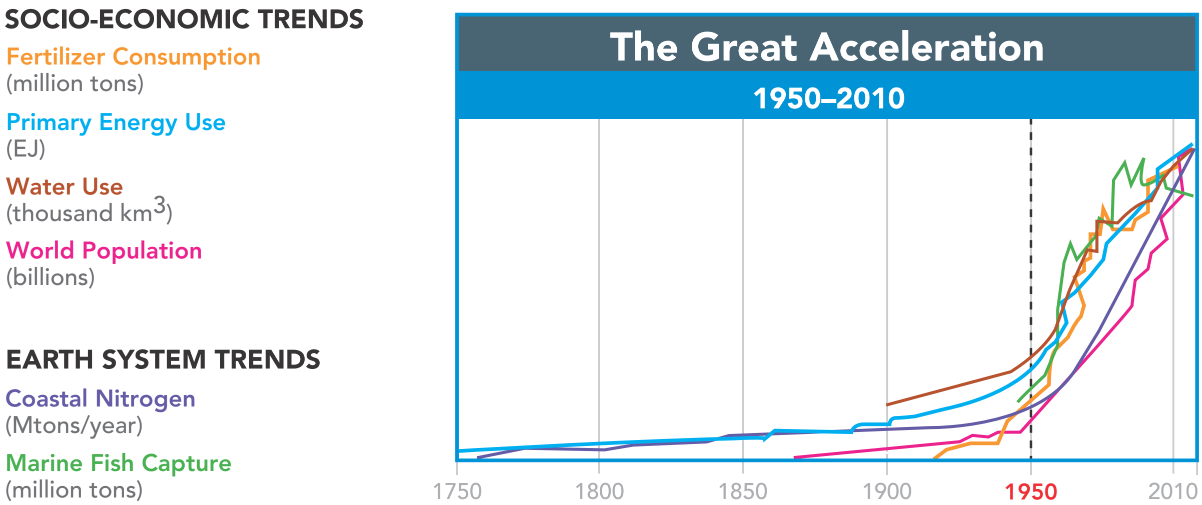
The Anthropocene Today, human activities drive global change. We move more sediment and rock every year than is moved by erosion and all the world's rivers. We have altered roughly three quarters of all land outside polar regions and mountain ranges. We fix and distribute vast quantities of nitrogen for fertilizer, dramatically altering the global nitrogen cycle. We've increased greenhouse gas levels to a concentration higher than the planet has seen for more than a million years. Many scientists feel that we are causing so many planet-wide changes, so quickly, that we should use a new name for the time period we're living in.

CASE STUDY

Figure 7-3

The Great Acceleration

Starting around the 1950s, the pace at which human activity affected Earth's resources skyrocketed.



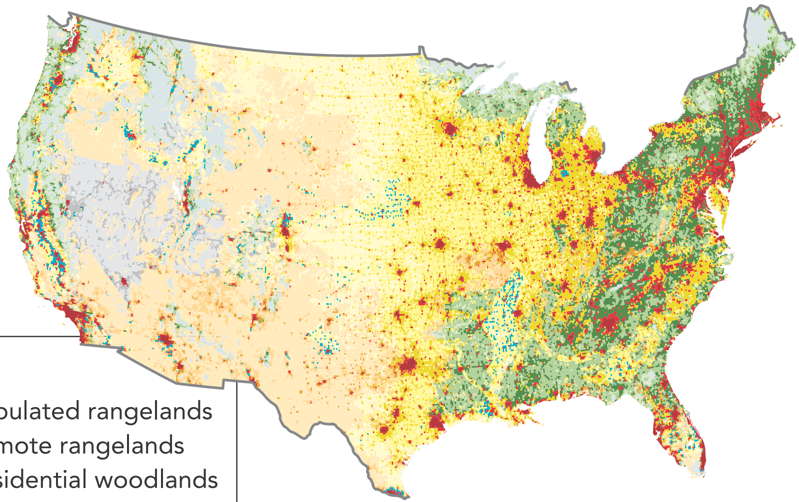
Sources: (1) Olivier Rousseau, IFA; IFA database. (2) A Grubler, International Institute for Applied Systems Analysis (IIASA); Grubler et al. (2012). (3) M Flörke, Centre for Environmental Systems Research, University of Kassel; Flörke et al. (2013); aus der Beek et al. (2010); Alcamo et al. (2003). (4) HYDE database; Klein Goldewijk et al. (2010). (5) Mackenzie et al. (2002). (6) Data are from the FAO Fisheries and Aquaculture Department online database (Food and Agriculture Organization-FIGIS (FAO-FIGIS), 2013).

INTERACTIVITY

Figure 7-4

Anthromes

The continental United States' human-altered biomes or anthromes, are shown on this map.



Adapted from: Map of Anthromes (v2; anthromes.org) based on Ellis, E. C., K. Klein Goldewijk, S. Siebert, D. Lightman, and N. Ramankutty. 2010. Anthropogenic Transformation of the Biomes, 1700 to 2000. *Global Ecology and Biogeography* 19:589-606.

The Anthropocene, or "age of humans," is the period during which human activity has become the major cause of global change. For this reason, as we discuss causes of global change in the twenty-first century, you will see that human causes of change occupy a larger portion of our global change model's outer ring than non-human causes.

INTERACTIVITY

Learn about habitat restoration and how it can increase biodiversity.

Anthromes: Human-Altered Biomes Recall that classic biomes no longer cover most land areas. What's in all those places now? Human-altered biomes that ecologists refer to as anthromes, or anthropogenic biomes. **Anthromes**, shown in **Figure 7-4,** are globally significant ecological patterns created by long-term interactions between humans and ecosystems. Examples of anthromes include cities, villages, croplands, and rangelands. Chances are that wherever you live, you are surrounded by anthromes rather than biomes. That doesn't mean that anthromes are "bad" or ugly. It does mean that there isn't a lot of untouched nature left.

HS-LS2-7

LESSON 7.1 Review

KEY QUESTIONS

1. What kinds of resources make up your ecological footprint?
2. Why are some scientists using the name *Anthropocene* to describe the current time period?

CRITICAL THINKING

3. **Cite Evidence** What evidence supports the argument that human activities are causing major changes to global systems?
4. **Use an Analogy** Buckminster Fuller compared Earth to a spaceship. During the period called the Great Acceleration, what changes affected the spaceship analogy?
5. **Design a Solution** Which part of your ecological footprint do you think could be reduced most significantly? Describe a method for reducing it.

LESSON

7.2 Causes and Effects of Global Change

KEY QUESTIONS

- *How do human activities change the atmosphere and climate?*
- *How do changes in the atmosphere drive climate change and other changes in global systems?*
- *How do the ways we use land drive change in global systems?*
- *What kinds of pollutants are drivers of global change?*

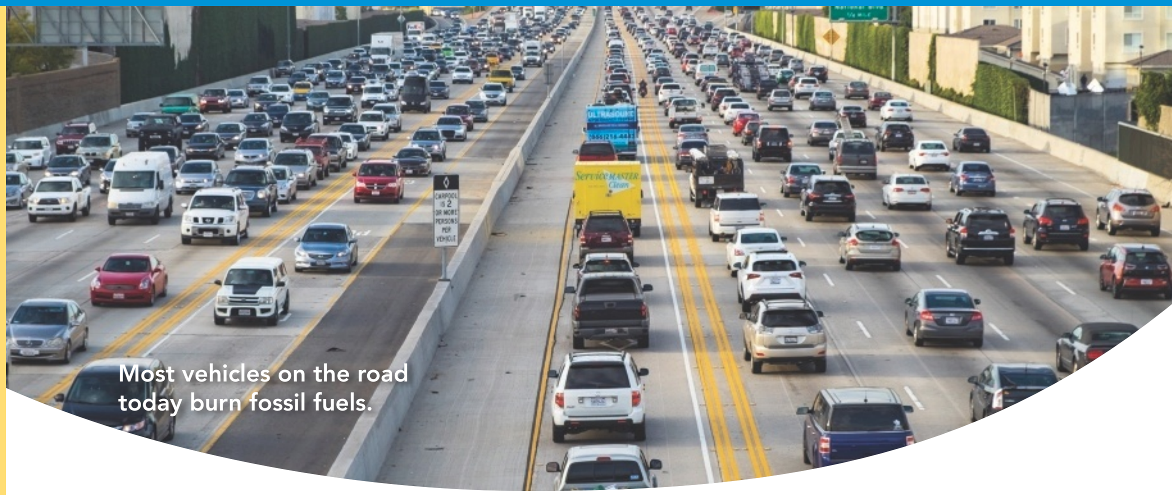
HS-LS2-2: Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales. **HS-LS2-7**: Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity. **HS-LS4-6:** Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity. **HS-ESS2-6:** Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere. **HS-ESS3-6:** Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.

VOCABULARY

climate change
global warming
deforestation • monoculture
invasive species • pollutant
ozone layer • smog
biological magnification

READING TOOL

For each heading in the lesson, explain the main idea in the table in your **Biology Foundations Workbook.** Then, list details that support and explain the main idea.



Most vehicles on the road today burn fossil fuels.

The Great Acceleration "promoted" us from spaceship Earth's passengers to crew. There's just one problem. This spaceship didn't come with an operating manual! We must understand how Earth systems work, and how our actions are changing them, in order to write that manual ourselves.

Human Causes of Global Change

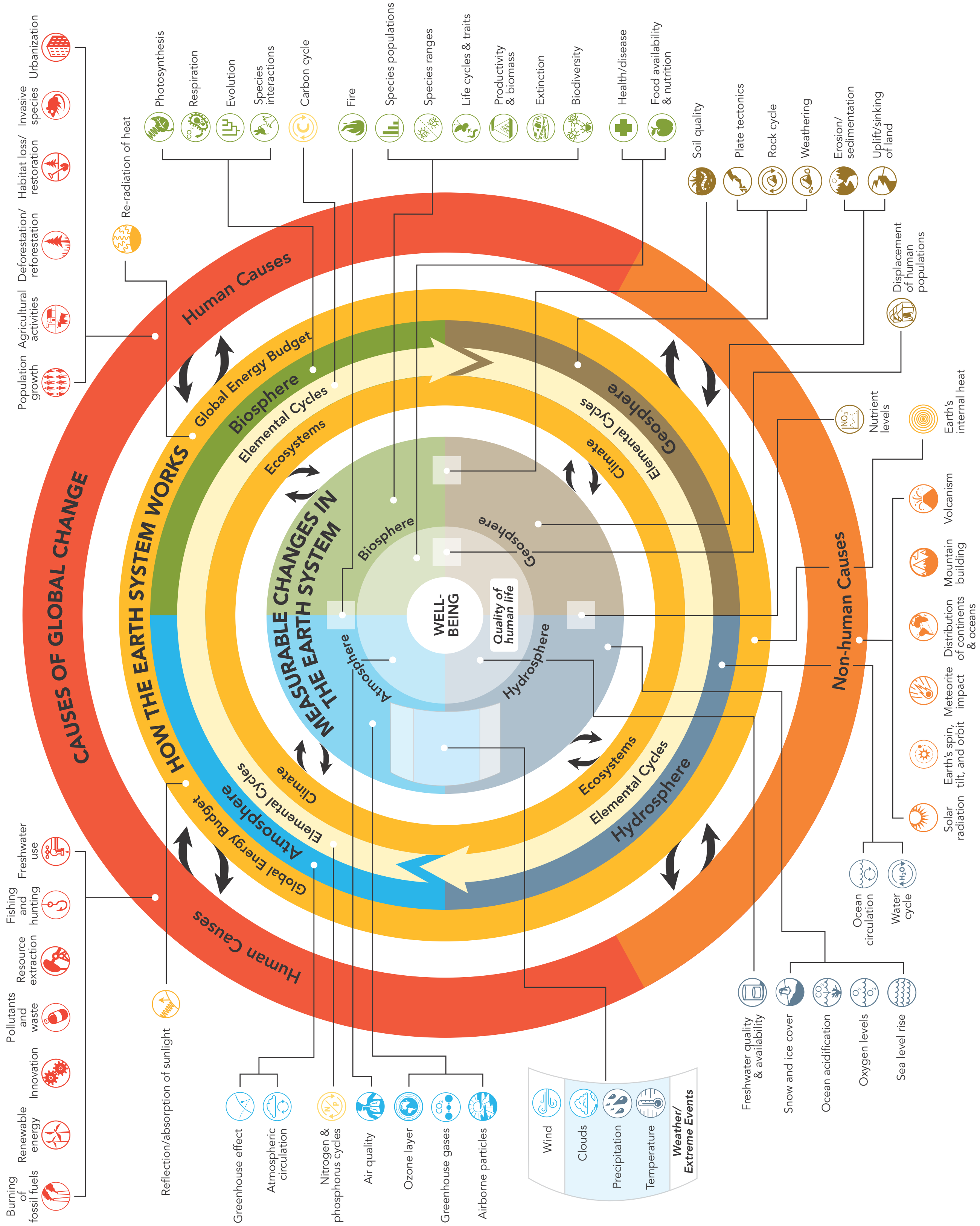
Throughout this unit, we've been building our Understanding Global Change (UGC) model, shown in **Figure 7-5**. We began with global systems, shown in the model's middle ring. We also discussed non-human causes of global change, shown in the lower portion of the model's outer ring. Ecological interactions and processes we discussed are in the model's "biosphere" section.

We will now focus on the human causes of global change, which occupy most of our model's outer ring. Why do they occupy so much space? Because all human activities combined are now more powerful drivers of change in global systems than non-human causes of change. ***Human activities affect global systems by changing the atmosphere in ways that change climate, changing the way we use land, over-harvesting some species, introducing species to new environments, and producing plastics and other pollutants.*** All these actions together create stress on organisms and ecosystems in ways that threaten biodiversity and ecosystem services. Note that the combined action of these human activities is more powerful than the effect of any single action alone. Note also that a single human activity, such as converting land to agriculture or burning fossil fuels, can affect several global systems in several ways. As we discuss each of these human activities in detail, keep referring back to Figure 7-5 to see how the activity fits into the Understanding Global Change model.

INTERACTIVITY

Figure 7-5
Understanding Global Change

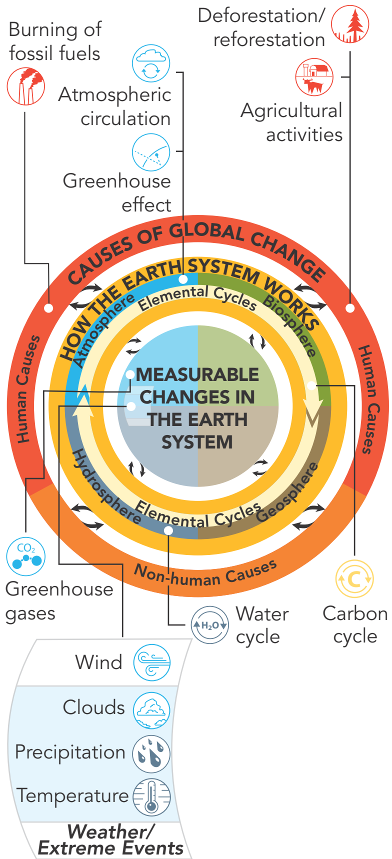
Processes and phenomena in the atmosphere, biosphere, geosphere, and hydrosphere interact to shape the Earth system. Both non-human factors and human activities affect the Earth system, resulting in measurable changes.



Adapted from the *Understanding Global Change Infographic*, © University of California Museum of Paleontology, Berkeley.

VIDEO

Learn about a disturbing area of the ocean that is saturated with trash.



Changing Atmosphere and Climate

We are currently subjecting Earth to an uncontrolled experiment in atmospheric chemistry. Human activity is changing Earth's atmosphere faster than it has changed during the entire history of life. Some activities raise concentrations of greenhouse gases, driving climate change. Other activities release different gases into the atmosphere, causing a variety of effects on global systems.

Fossil Fuels and the Atmosphere Quantitative data gathered over decades confirm two scientific facts. First, one data set confirms that atmospheric carbon dioxide concentrations have been rising since the Industrial Revolution. Second, other data show that most of that carbon dioxide is released by burning fossil fuels.

Climate Change **Climate change** is defined as measurable long-term changes in averages of temperature, clouds, winds, precipitation, and the frequency of extreme weather events such as droughts, floods, major storms, and heat waves. Climate change as we are experiencing it now is caused by the increase in average global temperatures often called **global warming**. Recall from Chapter 3 that the global climate system is powered by the total amount of heat retained within the atmosphere, and is shaped by the distribution of heat between the equator and the poles. That's why the strength of the greenhouse effect is so important. ***Higher concentrations of greenhouse gases, such as carbon dioxide and methane, trap more heat in the biosphere and cause global warming, which drives climate change.***

Climate change is a threat to biodiversity and ecosystem stability. Organisms have specific tolerance ranges to abiotic factors. ***If climate change alters environmental conditions beyond organisms' tolerance ranges, they must adapt, move to a more suitable location, or face extinction. For those same reasons, climate change can have major impacts on agriculture.***

HS-LS2-2

CASE STUDY **Quick Lab** **Guided Inquiry**

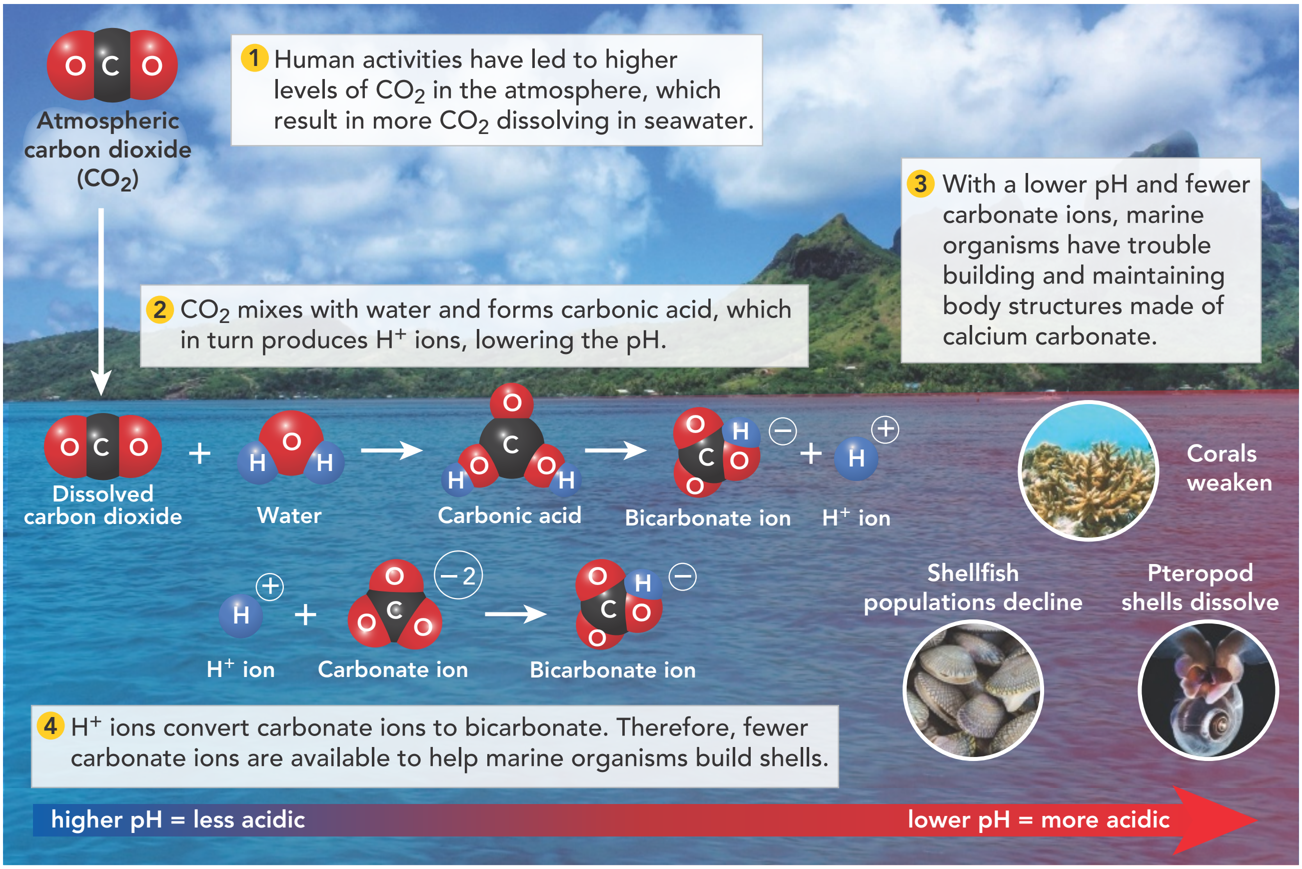
How Does Acid Affect Shells?

Vinegar is a solution of acetic acid. Mix vinegar and water in 5 beakers. Put only water in one beaker, only vinegar in another beaker, and mixtures of varying concentrations in the other beakers. Label each beaker with its contents and the concentration of vinegar (if appropriate).

1. Place 6 to 10 crushed pieces of egg shells in each beaker.
2. Wait one day. Then pour out the liquid from each beaker, and place the egg shell pieces on a paper towel. Examine the egg shell pieces.

ANALYZE AND CONCLUDE

1. **Observe** How did vinegar affect the egg shell pieces? Make a chart to record your observations.
2. **Draw Conclusions** Egg shells are made of calcium carbonate. How could ocean acidification affect corals, lobsters, snails, and other marine organisms that also have skeletons or shells made of calcium carbonate?
3. **Construct an Argument** How could ocean acidification become a severe problem? Use evidence and logical reasoning to support your answer.



Acid Rain Burning fossil fuels also releases sulfur dioxide and nitrous oxides that dissolve in fog or raindrops to form sulfuric acid and nitric acid. This creates acid rain, fog, and snow that affect nutrient cycling. Acid rain damages plant leaves and harms roots by releasing aluminum and other metals from some soils. Soil acidification can interfere with bacterial decay. The acidification of fresh water kills aquatic organisms from algae to fishes.

Ocean Acidification A significant amount of carbon dioxide released by burning fossil fuels dissolves in seawater, where it drives a chemical reaction that produces an acid, as shown in **Figure 7-6**. This process, called ocean acidification, poses serious problems for marine life. Many marine organisms, from plankton to corals and shellfish, build skeletons from calcium carbonate that they remove from seawater. When seawater is more acidic, these organisms must expend more energy to build their skeletons. So ocean acidification stresses many marine organisms and ecosystems.

Nitrogen Enrichment From Fossil Fuels Nitrogen released by burning fossil fuels travels through the air in dry form as tiny particles, or dissolved in water droplets. This nitrogen may therefore fall far from its source. Because nitrogen is a limiting nutrient for primary producers, nitrogen enrichment from burning fossil fuels can cause algal blooms.

CASE STUDY

Figure 7-6

Ocean Acidification

Many marine organisms—such as plankton, coral, pteropods, and shellfish—build skeletons from calcium carbonate. Carbon dioxide dissolves in seawater to form carbonic acid. Both the decrease in pH and the consumption of carbonate ions harm marine life.

Agriculture and the Atmosphere Agriculture is a widespread human activity because it provides a dependable food supply. Certain agricultural practices release methane, an even more powerful greenhouse gas than carbon dioxide. Methane is produced and released through cattle farming and the cultivation of rice in flooded paddies. Methane contributes to global warming and other changes in Earth's climate system.

Changes in Land Use

It takes a lot of land to provide housing, food, and energy for people! Human activity has already transformed roughly three quarters of Earth's land surface in several ways and for several reasons.

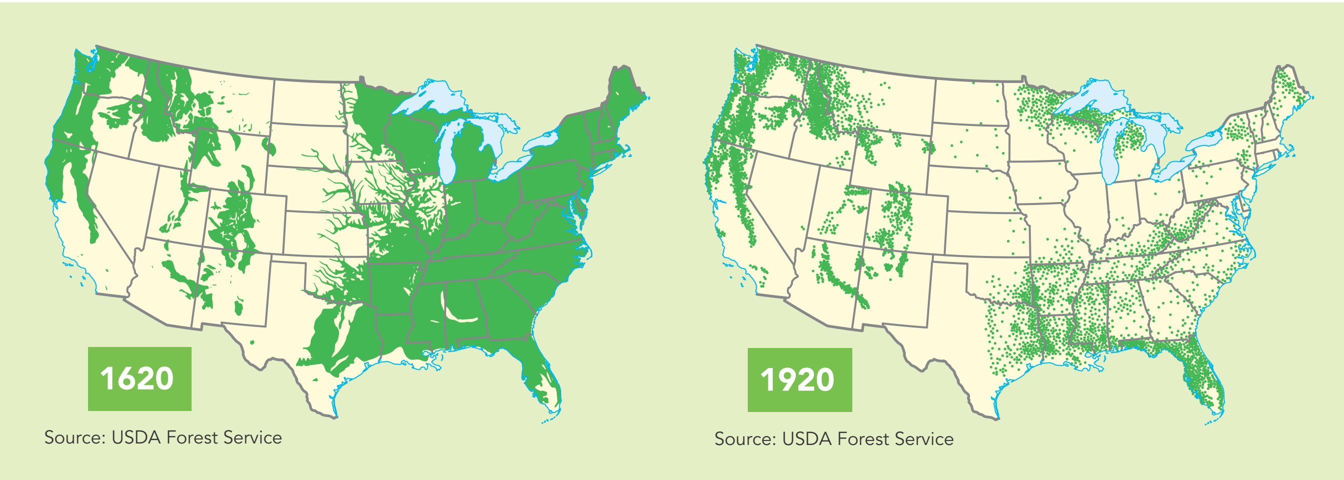


Figure 7-7

Primary Forest

Between 1620 and 1920, roughly 90 percent of the primary forests that once covered the United States were cut for lumber, farming, or both.

Deforestation/Reforestation Healthy forests hold soil in place, protecting the quality of freshwater supplies, absorbing carbon dioxide, and moderating local climate. When forests are lost, those ecosystem services disappear.

Deforestation The cutting of forests for lumber or farming, or **deforestation**, has altered natural environments. Most of us live in places that haven't been in a natural state for a long time, as **Figure 7-7** shows. ***Deforestation can affect water quality in streams and rivers. In mountainous areas, deforestation increases soil erosion, which can cause landslides.***

Natural Regrowth Through Succession Most forests east of the Mississippi River are secondary forests that grew back after primary forests were cut. In some places, logged areas can undergo secondary succession, so forests can regrow. In tropical rain forests, on the other hand, topsoil is thin, and organic matter decomposes rapidly. If small areas of tropical rain forests are cleared and left alone, secondary succession can occur and restore biodiversity. If large tropical forest areas are cleared, natural regrowth may not be possible.

Reforestation Scientifically guided reforestation, or replanting of forests, can replace trees that have been cut for lumber, fuel, or agriculture. Reforestation efforts by local communities around the world are bringing back forests and restoring ecosystem services. One of the most important ecosystem services that reforestation can restore is the provision of dependable, clean drinking water. **Figure 7-8** shows reforestation work by a local Mayan community in Totonicapán, Guatemala, where deforestation had caused local streams and springs to dry up. Those water sources are now returning.

Figure 7-8

Reforestation

Scientifically-informed, grassroots reforestation, guided by long-term partnership between local communities and the non-governmental organization EcoLogic Development Fund, is restoring the integrity of local watersheds in Totonicapán, Guatemala.

Agriculture

During the Great Acceleration, agriculture provided food for our growing population using a mixture of agricultural practices called the "Green Revolution." Today, agricultural activities cover more of Earth's land surface than any other human activity.

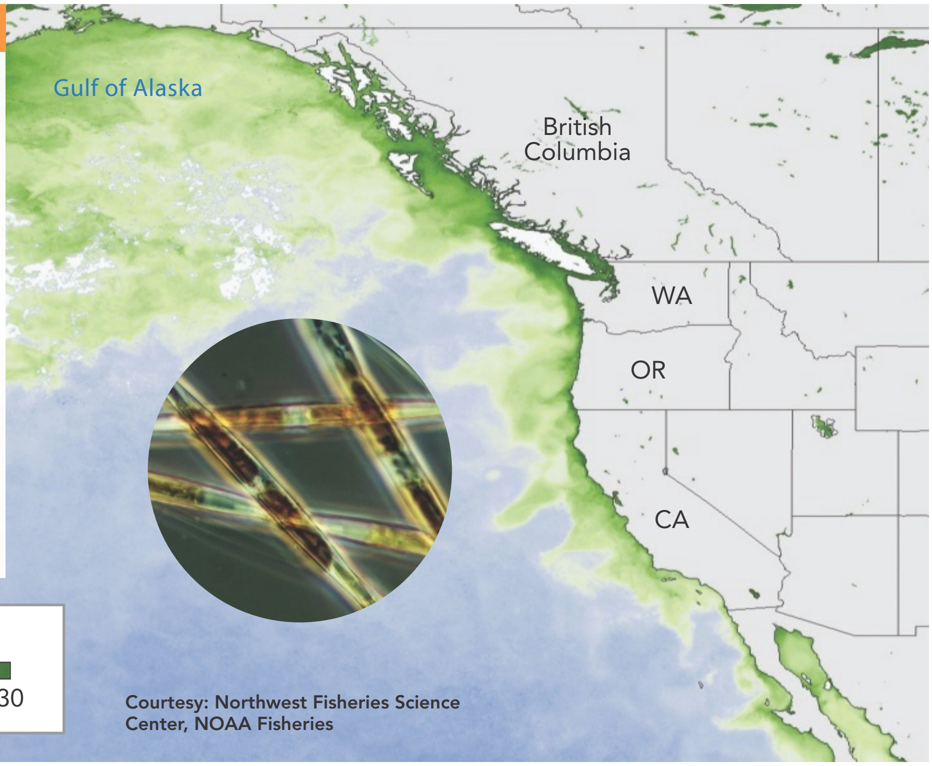
Monoculture The Green Revolution was based on a strategy called **monoculture**, which involves planting large areas with a single highly productive crop year after year. Monoculture enables efficient sowing, tending, and harvesting. However, most large-scale monocultures require lots of artificial fertilizers and pesticides. ***When large areas are used for grazing, or to grow monocultures for long periods, fertilizers and pesticides can change soil structure and microbiomes in ways that degrade soil and prevent secondary succession.***

CASE STUDY

Figure 7-9

Toxic Algal Bloom

In July 2015, an enormous algal bloom stretched from California to Alaska. One of the algae involved in the bloom was the marine diatom *Pseudo-nizchia*, shown in the inset. This algae produces a toxin that builds up in the food chain and can poison fish, seabirds, marine mammals, and humans.



Nitrogen Enrichment From Agriculture Humans use industrial processes to fix atmospheric nitrogen to make fertilizer. This added nitrogen fueled the Green Revolution and helped avoid global famine by dramatically increasing food production. Today, fertilizer manufacture and application has more than doubled the amount of biologically active nitrogen cycling through the biosphere, dramatically changing the natural nitrogen cycle. A lot of that nitrogen "leaks" out of agriculture, usually in soil water runoff. Too much nitrogen in streams and rivers can upset the balance in freshwater and marine ecosystems, as shown in **Figure 7-9**.

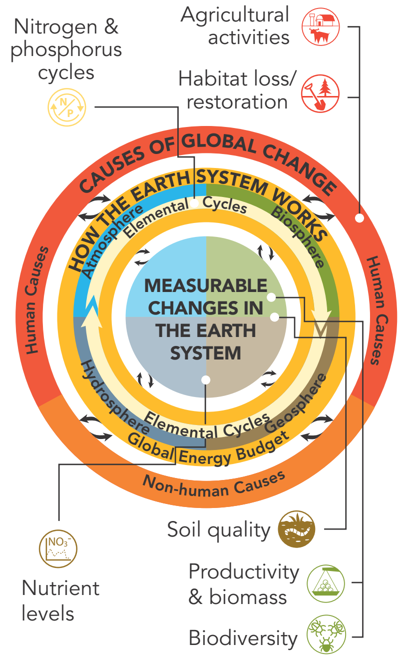
Figure 7-10

Cities

Large cities such as Chicago produce huge amounts of waste that must be removed every day.

Development/Urbanization As modern societies develop, many people move to cities like the one in **Figure 7-10**, and to suburbs around those cities. Suburban development consumes farmland and divides natural habitats into fragments. Roughly two thirds of Americans live in urban areas today, and migration to cities is increasing in developing countries around the world. These dense human communities produce large amounts of wastes. If these wastes are not disposed of properly, they affect air, water, and soil resources.

One result of urbanization has been an increase in the production of sewage, which includes everything you flush down the toilet or the drain. In some cities, sewage includes runoff from roofs, sidewalks, and streets. Sewage isn't poisonous, but it does contain lots of nitrogen and phosphorus. Reasonable amounts of these nutrients can be processed and absorbed by healthy ecosystems. Large amounts of sewage can disrupt nutrient cycles and stimulate the growth of toxic or ecologically damaging blooms of bacteria and algae. Raw sewage also contains microorganisms that can spread disease.



Habitat Loss, Fragmentation, and Restoration

Human-caused changes in natural habitats can occur in a number of ways and for several reasons. These include habitat loss, habitat fragmentation, and habitat restoration.

Habitat Loss When natural habitats are completely changed, species that once lived in that area either emigrate or disappear. Habitats can be lost to urban, suburban, or industrial development, as well as to logging or agriculture.

Habitat Fragmentation Habitats don't need to be completely destroyed to put species at risk. Development and agriculture can split ecosystems into pieces, a process called habitat fragmentation. You can think of ecosystem fragments as habitat "islands." You probably think all islands are land surrounded by water. But a biological island can be any patch of habitat surrounded by a different habitat, as shown in **Figure 7-11**. The smaller a habitat fragment is, the smaller the number of species that can live there, and the smaller the populations the fragment can support. ***Habitat fragmentation causes biodiversity loss and makes ecosystems more vulnerable to other disturbances.***

Habitat Restoration Under some conditions, and with a great deal of work, damaged habitats can be repaired. Ecological restoration aims to recreate, in a degraded area, conditions that resemble as closely as possible the ecosystem that existed before it was disturbed. Wetlands may be restored by removing material originally used to fill them. Degraded estuaries may be improved by dredging to increase tidal flow, or to reestablish the natural flow of rivers feeding the estuary.

READING CHECK Identify What is the relationship between habitat size and the number of species that can live there?

BUILD VOCABULARY

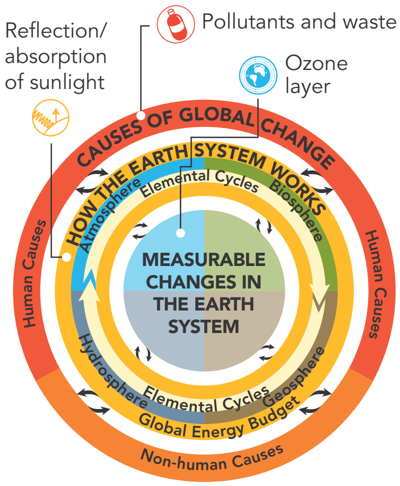
Related Words The noun fragment means "a small broken-off piece." The verb *fragment* means "to break or cause to break into fragments." The noun *fragmentation* refers to the action of breaking up or being broken up.

Figure 7-11
Biological Islands

A cattle pasture now surrounds this remnant of forest, making the forest a biological island.

Figure 7-12

Human Activity and Global Change



Hunting and Fishing Many animals are hunted and fished for food or are hunted for hides, feathers, body parts believed to have medicinal properties. Humans have hunted species to extinction for thousands of years. Illegal hunting of animals threatens many species, including gorillas and elephants. Elephants are often hunted for the ivory in their tusks.

Overfishing has caused declines in fish populations around the world. In the United States, endangered species are protected from hunting. The Convention on International Trade in Endangered Species (CITES) bans international trade in products from endangered species, but it's difficult to enforce laws in remote wilderness areas.

Invasive Species Recall that organisms introduced to new habitats can sometimes experience exponential population growth and become invasive species because they lack predators and parasites in their new homes. If these organisms are **invasive species**, they can cause tremendous harm. An invasive species is any nonnative species whose introduction causes, or is likely to cause, economic harm, environmental harm, or harm to human health. Ecological disruption caused by invasive species can drive native species to extinction. Most invasive species are carried to new habitats by human trade and travel. Ecological problems caused by invasive species around the world have grown to the point where they are included as drivers of global change. There are roughly 3000 invasive species in the United States alone. The purple loosestrife in **Figure 7-13** is just one example of an invasive species.

INTERACTIVITY

Investigate the impact humans have on ecosystems through pollution, farming, hunting, building, and overfishing.

Pollution

A **pollutant** is any harmful material created as a result of human activity and released into the environment. Many pollutants threaten biodiversity. Certain kinds of air pollution are local concerns, but others act globally. And some pollutants once considered "local problems" are now known to have global effects. ***Common forms of air pollution include smog, greenhouse gases, heavy metals, and aerosols. The primary sources of water pollution are industrial and agricultural chemicals, residential sewage, and nonpoint sources.***

Figure 7-13

Invasive Species

Purple loosestrife is growing in dense stands, displacing the native plants that wetland animals use for food and nesting grounds.

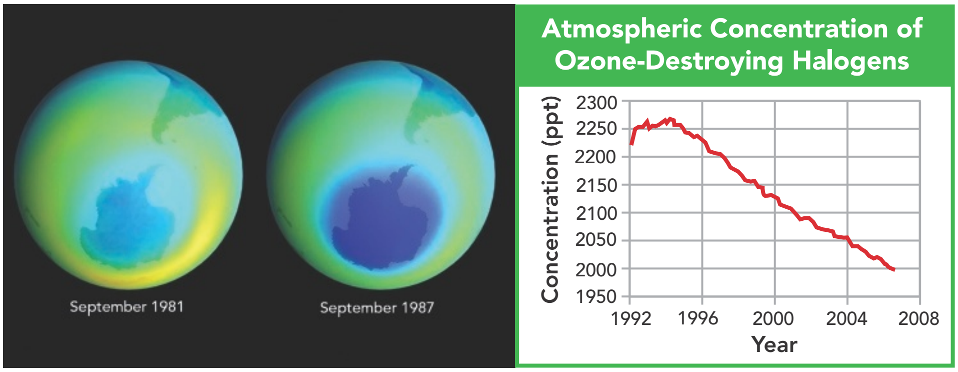


Figure 7-14

Ozone Hole

In these satellite images, the size and intensity of the blue region increased from 1981 to 1999, indicating a thinning of the ozone layer over Antarctica. The graph shows how the levels of atmospheric halogens have decreased since legislation was passed to ban CFCs.

CFCs and Stratospheric Ozone Chlorofluorocarbons (CFCs) are industrially produced gases. They once were widely used as propellants in aerosol cans and fire extinguishers, as coolants in refrigerators and air conditioners, and in the production of plastic foams. A few decades ago, the use of CFCs was tied to the destruction of ozone in a section of the upper atmosphere called the stratosphere. This high-level ozone, called the **ozone layer**, absorbs ultraviolet light, acting like a global sunscreen. Beginning in the 1970s, satellite data revealed that the ozone concentration over Antarctica was decreasing, as shown in **Figure 7-14**. The area of lower ozone concentration was called an "ozone hole." For several years after the hole was discovered, ozone concentrations continued to drop, and the hole grew larger and lasted longer every year.

No one could explain this phenomenon until three researchers made a breakthrough that earned them a Nobel Prize. In 1974, researchers demonstrated that CFCs act as catalysts to destroy ozone molecules under conditions in the upper atmosphere. This research led to hypotheses that were tested in several ways. Research flights over the poles gathered data demonstrating that CFCs combine with ice crystals in frigid air in a way that allows sunlight to destroy ozone. Once this research was published and accepted by the scientific community, the rest was up to policymakers and industry—as you will learn in the next lesson.

Ground-Level Ozone Ozone in the upper atmosphere is a good thing, but ozone at ground level is not. If you live in a large city, you've probably seen **smog**, a gray-brown haze formed by chemical reactions among pollutants released by industrial processes and automobile exhaust. Ozone is one product of these reactions. Ozone and other pollutants at ground level threaten human health, especially for people with respiratory conditions. Many athletes in the 2008 Summer Olympics in Beijing, China, expressed concern that the intense smog, seen in **Figure 7-15**, would affect their health and performance. In the United States, automobile emission standards and clean-air regulations have improved air quality in many cities.

Figure 7-15

Smog

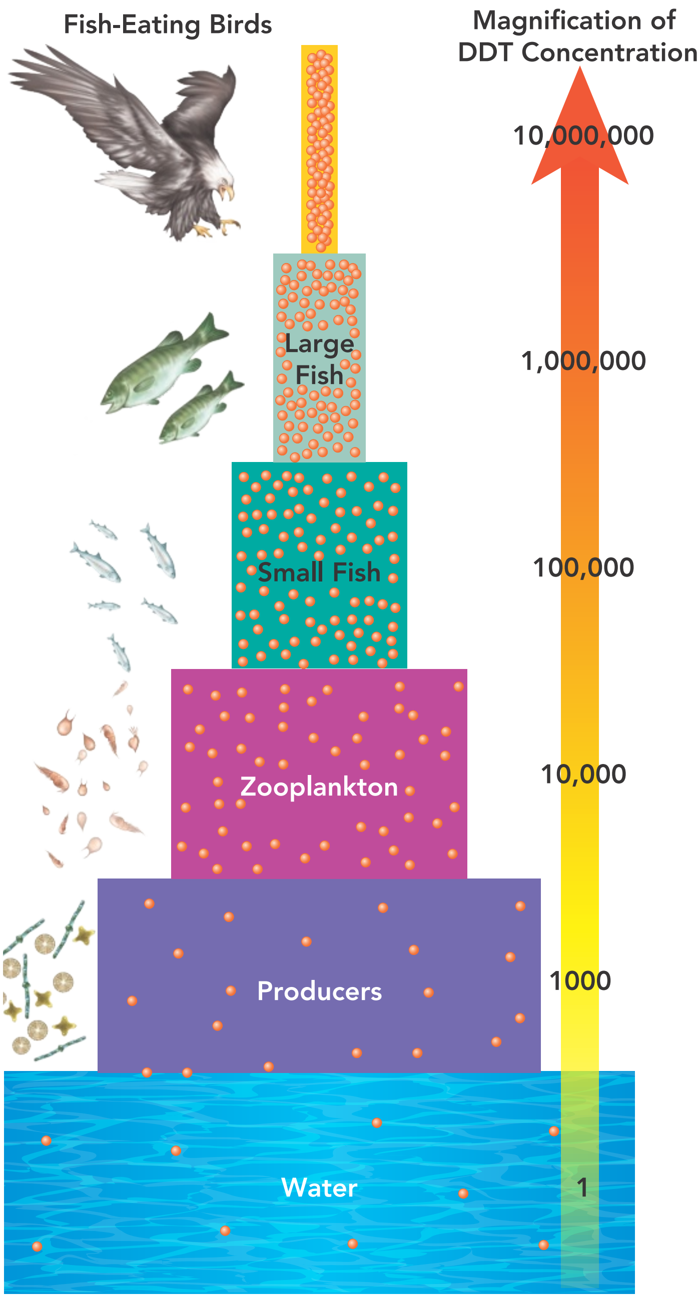
Despite closing factories and restricting vehicle access to the city, Beijing remained under a dense blanket of smog just days before the 2008 Summer Olympics.

Industrial and Agricultural Pollution Industry, science, and technology provide us with the conveniences of modern life—and require energy. We produce most of this energy by burning fossil fuels that release greenhouse gases and other pollutants. Since the Industrial Revolution, many industries have discarded wastes from manufacturing and energy production into air, water, and soil. Large-scale monoculture increased the use of pesticides and insecticides. These chemicals can enter the water supply in the form of runoff after heavy rains, or they can seep directly into groundwater. This type of pollution is called nonpoint source pollution.

Figure 7-16

Biological Magnification

In the process of biological magnification, the concentration of a pollutant like DDT—represented by the orange dots—is multiplied as it passes up the food chain from producers to consumers.



Biological Magnification When certain pollutants are picked up by organisms, the pollutants are not broken down or eliminated. Instead, they collect in body tissues. Primary producers can absorb pollutants, even if those pollutants are present in the environment in very low concentrations. Herbivores that eat those producers store the pollutant and concentrate it further. When carnivores eat herbivores, pollutants are further concentrated. In the highest trophic levels, pollutant concentrations may reach 10 million times their original concentration in the environment, as shown in **Figure 7-16**. The process in which pollutants are concentrated as they pass through trophic levels is called **biological magnification**. These high concentrations can cause serious problems for wildlife and humans.

DDT One of the first widely used pesticides, DDT, is cheap, long lasting, and effective at controlling agricultural pests and disease-carrying mosquitoes. But when DDT gets into a water supply, it is concentrated by biological magnification and can have disastrous effects. Widespread DDT use in the 1950s threatened fish-eating birds like pelicans, osprey, falcons, and bald eagles. It caused females to lay eggs with thin, fragile shells, reducing hatching rates and causing a drop in bird populations. Since DDT was banned in the 1970s, bird populations have been recovering.

PCBs One industrial water pollutant is a class of toxic organic chemicals called PCBs (polychlorinated biphenyls), which were widely used in industry until the 1970s. PCBs have been banned, but they persist in the environment and accumulate in food webs through biological magnification. Mud and sand in parts of the Great Lakes and some coastal areas are still polluted with PCBs today.

Heavy Metals Other harmful industrial pollutants are heavy metals like cadmium, lead, mercury, and zinc. Heavy metals also accumulate in food webs and pose health threats. Mercury, for example, accumulates in certain marine fishes such as tuna and swordfish. Even at low concentrations, mercury and lead can cause neurological problems in young children and adults.

Although the country's lead levels still need to improve, the current situation demonstrates the positive effects of scientifically informed environmental legislation. At one time, all gasoline was enriched with lead. But as leaded gasoline burned, lead was released in exhaust fumes and washed onto land and into rivers and streams. U.S. efforts to phase out leaded gasoline started in 1973 and were completed in 1996, when the sale of leaded gasoline was banned. Now that unleaded gasoline is used widely, lead levels in soils, rivers, and streams around the country have dropped significantly, as shown in **Figure 7-17**.

READING TOOL

Once you have finished reading this lesson, go back and make a supporting details web showing the many ways in which the environment is affected by the actions of humans.

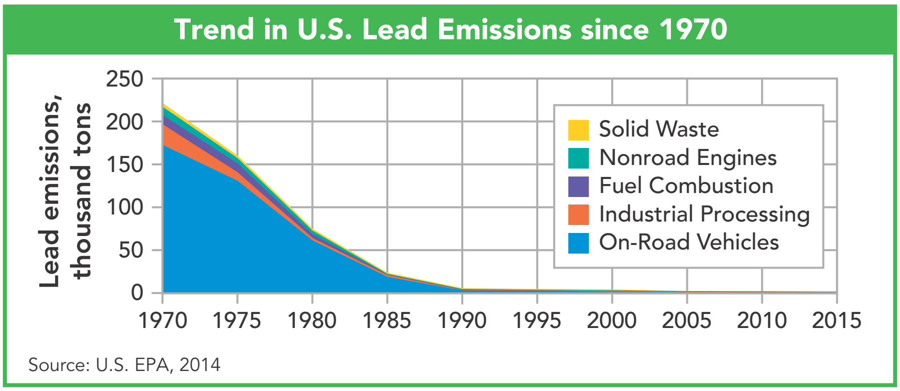


Figure 7-17

Get the Lead Out

The lead from car exhaust proved a dangerous pollutant. Transitioning from leaded to unleaded gasoline has resulted in a decline of lead emissions in the United States.

HS-LS2-2, HS-LS2-7, HS-LS4-6, HS-ESS2-6, HS-ESS3-6

LESSON 7.2 Review

KEY QUESTIONS

1. Why do human causes of global change occupy a larger portion of the global change model than nonhuman causes?
2. What is the relationship between global warming and global climate change?
3. Explain one way that land use by humans affects nutrient cycles.
4. What kinds of harmful changes can pollution cause?

CRITICAL THINKING

5. **Use Models** Explain three cause and effect relationships between the human activities and the measurable changes in the Earth system represented in the Understanding Global Change model.
6. **Design a Solution** What is a possible solution for preventing the loss of biodiversity by habitat fragmentation?
7. **Analyze** Food production is an ecosystem service. Explain how human activities are affecting this ecosystem service.
8. **CASE STUDY** How is ocean water becoming more acidic?

LESSON 7.3

Measuring and Responding to Change

This researcher is collecting samples of glacial ice.

KEY QUESTIONS

- *What evidence supports the claims that the climate is changing?*
- *What are some impacts of climate change?*
- *What is the role of science in responding to global change?*

HS-LS2-7: Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

HS-ETS1-1: Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

HS-ESS3-4: Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.

HS-ESS3-5: Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems.

HS-ESS3-6: Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.

READING TOOL

Complete the graphic organizer in your **Biology Foundations Workbook** with the possible effects and solutions of climate change.

In recent years, bodies of ancient humans have been emerging from melting glaciers. One of the first, nicknamed Ötzi and found in the Italian Alps, died 5300 years ago. Ötzi stayed frozen until rising temperatures melted the ice above him.

Climate Change: The Data

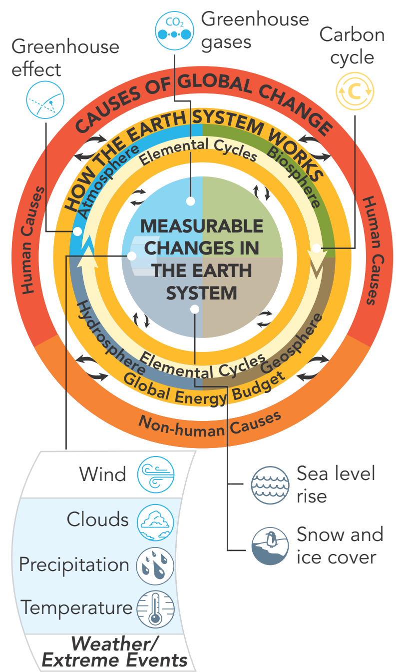
Ötzi's emergence from the ice led Worldwatch Institute to suggest that "Our ancestors are emerging from the ice with a message for us: Earth is getting warmer." That dramatic announcement got public attention. But scientists need data.

IPCC Climate Data The most reliable climate data come from the Intergovernmental Panel on Climate Change (IPCC). The IPCC is an international organization established to provide the best possible scientific information on climate change. IPCC reports contain data and analyses that have been agreed upon and accepted by more than 2500 international climate scientists and all governments participating in the study. The most recent IPCC report from 2014 makes a strong case that global climate is changing and that human activity influences climate.

Climate Changes Data indicate that Earth is warming, and that the warming is greater than anything in recorded history. ***Data show that both the atmosphere and the oceans have been warming; that sea levels are rising; and that Arctic sea ice, glaciers, and snow cover are all decreasing.*** Data on sea ice, sea level, and CO_2 emissions are shown in **Figure 7-18**. The greatest changes are occurring in and near the Arctic Circle. Average temperatures in Alaska, for example, increased 2.4 degrees Celsius over the last 50 years.

Human Activity Influences Climate The latest IPCC report states firmly that "Human influence on the climate system is clear, and recent anthropogenic emissions of greenhouse gases are the highest in history."

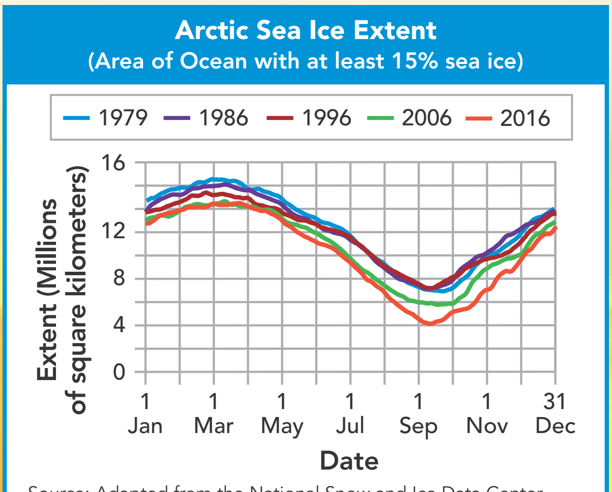
Modeling With Data Researchers use data to construct computer models to predict future climate trends. The most widely accepted models predict that average global temperatures will increase somewhere between 0.3 and 1.7 degrees Celsius above their year 2000 level by the end of the twenty-first century if all the world's countries agree on very strong measures to curb greenhouse gas emissions. If emissions continue increasing as they have been in recent years, the global temperature could increase somewhere between 2.6 and 4.8 degrees Celsius by the year 2100.



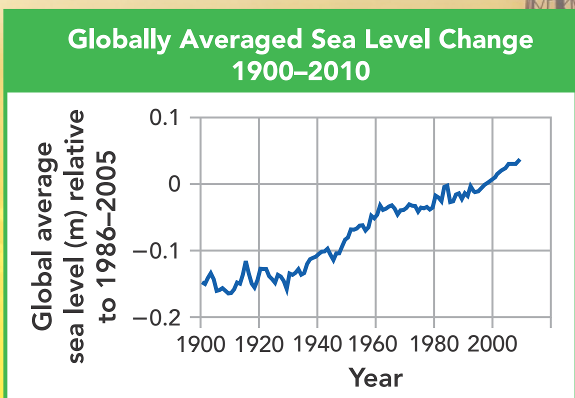
CASE STUDY

Figure 7-18 **IPCC Data**

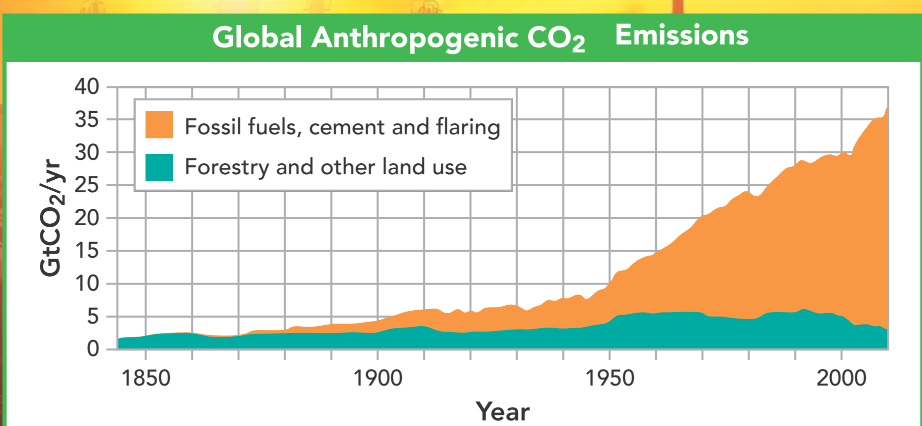
These diagrams represent just a small part of the data from the 2014 report from the Intergovernmental Panel on Climate Change. Human activities are altering global climate. Recent anthropogenic emissions of greenhouse gases are the highest in history.



Source: Adapted from the National Snow and Ice Data Center, Boulder, CO



Source: Based on data from the Intergovernmental Panel on Climate Change. Only one data set is shown.



Quantitative information of CH_4 and N_2O emission time series from 1850 to 1970 is limited.
Source: Adapted from Intergovernmental Panel on Climate Change.

READING TOOL

Predict the main idea of this lesson from what you have already read. At the end of the lesson, check your prediction to determine whether you were correct.

INTERACTIVITY

Identify the impacts of climate change.

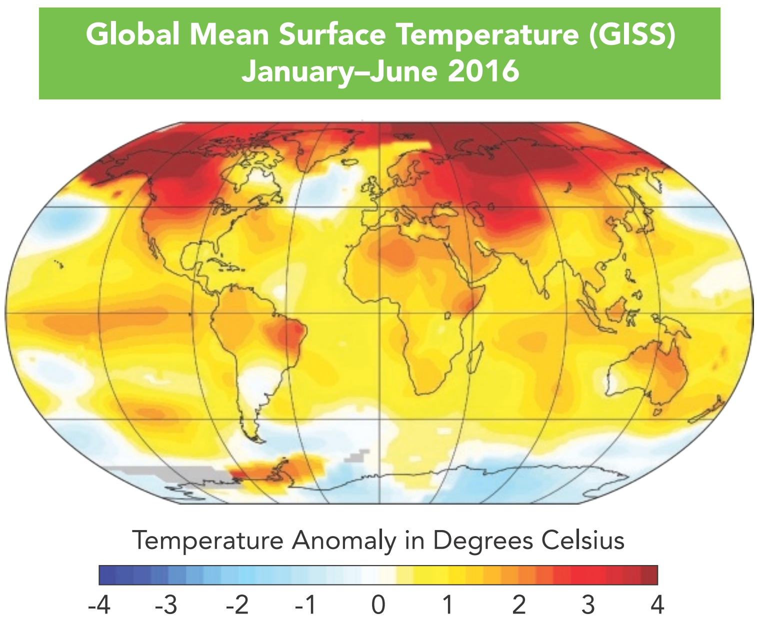
Climate Change Impacts

The IPCC report concludes: "… changes in climate have caused impacts on natural and human systems on all continents and across oceans." As you learned earlier, climate change includes much more than just the direct effects of warming. ***Total precipitation and seasonal distribution of precipitation are changing. Heat waves are expected to become longer and more intense. Many areas will experience more episodes of extreme heat and storms.***

One reason for those changes is that temperatures are increasing faster in the Arctic than they are in the temperate zone and tropics, as you can see by the red areas in the map in **Figure 7-19**. Recall that the global climate system is powered and shaped both by the total amount of heat retained by the atmosphere and by the difference in temperatures between the polar regions and warmer areas. As the poles warm more than the temperate zone, that difference in temperature decreases. This affects both the speed and the behavior of major winds such as the jet stream.

Figure 7-19
Increasing Temperatures

Higher-than-normal temperatures are shown in yellow and red. The highest above-normal temperatures (red) are concentrated in the Arctic region.



Source: NASA/GISS

Figure 7-20
Ecological Impacts on Organisms

Hummingbirds are arriving in their breeding grounds earlier every year.

Ecological Impacts

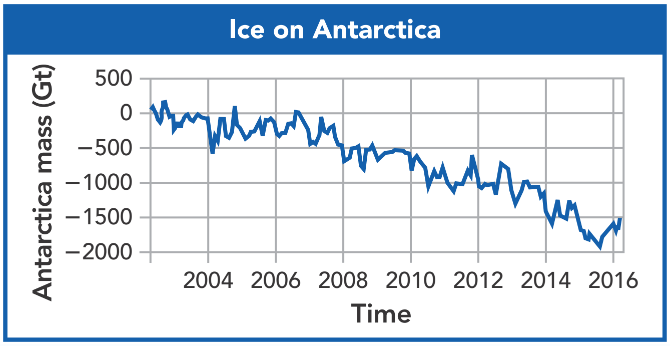
Small changes in climate can affect organisms and ecosystems. Remember that each organism's geographic range is determined by its tolerance to ranges in temperature, humidity, and rainfall. If conditions change beyond an organism's tolerance, the organism must adapt, move to a more suitable location, or face extinction. For example, if the temperature rises, organisms move away from the equator toward cooler places. They also move from warm lowlands to cooler, higher altitudes.

CASE STUDY Analyzing Data

Evidence in Ice

Since 2002, NASA has used satellites to measure the mass of ice on Antarctica. The data is shown in the line graph.

1. **Interpret Graphs** What is the overall trend in the mass of ice on Antarctica?
2. **Evaluate Evidence** How do the data support the conclusion that Earth's climate is warming?
3. **Predict** How do you think the mass of Antarctic ice will change in the future? Cite evidence and use logical reasoning to support your prediction.



Source: NASA

4. **Connect to Society** Explain why it is important for scientists to collect and monitor Antarctic ice data.

Life cycles of many plants and animals are cued by seasonal changes in temperature. Plant flowering and animal breeding are sensitive to both daytime and nighttime temperatures. If warming is occurring, researchers hypothesize that organisms should respond as though spring were beginning earlier. Data from studies covering more than 1700 plant and animal species confirm that those organisms' life cycles are shifting as though they were experiencing rising temperatures. For example, hummingbirds like the one shown in **Figure 7-20** are changing the timing of their migration, arriving in their summer breeding grounds earlier every year. Globally, climate change alone threatens a great many species with extinction. Add climate change to all the other human-caused changes in global systems, and the result is that many more organisms—and entire ecosystems—are at risk.

Impacts on Human Systems Changes in temperature and precipitation have already begun to negatively affect crop yields of corn and wheat in some places. Water availability is changing in many agricultural areas, and is expected to affect farming in years to come. For example, the average winter snowpack in the western mountains of the United States is decreasing and is melting earlier in the spring. Farmers depend on water stored in this snowpack and the timing of its summer melt. Several areas in the western and southwestern United States are experiencing more droughts during the summer growing season.

Sea Level Rise Global warming also affects sea level. Sea level has risen, on average, at a rate of 1.8 millimeters every year since 1961. This increase has two causes. Melting ice from glaciers and polar ice caps add water to the oceans. In addition, a lot of the extra heat retained by the atmosphere is absorbed by the oceans. As oceans warm, their water expands slightly. Although this expansion might not seem like much, when you think of ocean basins a mile or more deep, even a small amount of expansion affects sea level.

BUILD VOCABULARY

Academic Words The noun expansion means "the action of becoming larger." The expansion of water when it warms ultimately leads to an increase in its volume. This, in turn, contributes to rising sea levels.

INTERACTIVITY

Figure 7-21

Success Story

The giant panda was removed from the endangered species list in September 2016.

Designing Solutions

The goal of science is to help us understand the natural world and to apply that knowledge to improve the human condition. Scientific data, properly collected, analyzed, and applied, can help us make vitally important decisions to positively affect the future of humanity. ***Scientific research can have a positive impact on the global environment by (1) recognizing a problem in the environment, whether from human or other causes, (2) gathering data to document and analyze that problem and identify its cause, and then (3) guiding changes in our behavior based on scientific understanding.***

Environmental Successes Several examples we've discussed show how research can guide us toward positive results for humanity and the biosphere. Take, for example, the presence of lead in streams in the U.S. The first step was to recognize that lead in water supplies was partly due to pollution from car exhaust. Then, industrial research figured out how to enable cars to run efficiently on unleaded fuel, and leaded gasoline was phased out. The successful global response to ozone depletion offers a model for international action based on scientific information. Once research connecting CFCs with ozone depletion was published, replicated, and accepted by the scientific community, the rest was up to policymakers and industry. Following scientific recommendations, 191 countries signed the Montreal Protocol, an agreement banning most uses of CFCs. Then, manufacturers developed alternatives to CFCs that work in most applications. Stratospheric ozone is now recovering!

Climate Change Challenge Of all the ecological challenges humanity has faced, climate change is the most complicated and difficult to fix. The world still depends heavily on fossil fuels and agriculture that produces methane. It will take a lot of effort to find solutions that work. Hopefully, governments around the world will let science inform their decisions on this globally important issue.

INTERACTIVITY

Investigate carbon sequestration by planning an urban tree planting.

HS-LS2-2, HS-LS2-7, HS-ETS1-1, HS-ESS3-4, HS-ESS3-5, HS-ESS3-6

LESSON 7.3 Review

KEY QUESTIONS

1. How does the climate change that scientists are observing now compare with climate change in the past?
2. How has climate change affected plant and animal species on Earth?
3. What actions have scientists already taken to help society address global climate change? What actions should be taken next?

CRITICAL THINKING

4. **Use Models** According to the climate models that scientists have developed, what variable will most affect the average increase in global temperature this century?
5. **Construct an Explanation** How can increasing temperatures in polar regions affect climate all across Earth?
6. **Evaluate Claims** Scientists claim that changes to global climate will affect both natural ecosystems and human systems, such as farms and ranches. Cite evidence and logical reasoning to evaluate this claim.

Sustainability

LESSON 7.4

KEY QUESTIONS

- *What criteria can be used to evaluate whether development is sustainable?*
- *Why are innovation and resilience important?*

HS-LS2-7: Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.
HS-LS4-6: Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.
HS-ETS1-1: Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.
HS-ESS3-4: Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.
HS-ESS3-5: Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems.

VOCABULARY
sustainable development
renewable resource
nonrenewable resource
resilience

READING TOOL
For each section of this lesson, take notes in your **Biology Foundations Workbook** about sustainable development and how it can be achieved.

VIDEO
Learn how the human taste for seafood is affecting the world's oceans.

Ecological science can help guide us to provide for human needs without causing long-term environmental harm. That guidance requires understanding everything you've learned in this unit—and more. Science alone isn't enough. Global planning requires input from economics, sociology, and other disciplines beyond the realm of this book. Here we will discuss only the scientific aspects of ecological planning for the future.

Sustainable Development

Using resources in ways that preserve ecosystem services is called **sustainable development**. Sustainable development recognizes the links between ecology and economics. You can think of sustainable development as three nested spheres: Earth's life support system (the environment), society, and the economy, as shown in **Figure 7-22**. This diagram symbolizes that our economy operates within society, and both operate within Earth's life support system.

Figure 7-22
Sustainable Development

This diagram symbolizes that the economy operates within society, which in turn operates within Earth's life support system.

Figure 7-23

United Nations Sustainable Development Goals

The United Nations has set 17 goals for sustainable development. In 2015, the organization promoted the goals on its headquarters building in New York City.

INTERACTIVITY

Investigate sustainable development.

READING TOOL

Identify details in the text that support sustainable development goals.

United Nations Sustainable Development Goals What should sustainable development aim for? ***Sustainable development should provide for human needs while preserving ecosystem services. It should cause no long-term harm to soil, water, and climate. It should consume as little energy and material as possible. Finally, sustainable development must take into account human needs and economic systems.*** It must do more than just enable people to survive. It must help them improve their situation. The United Nations has set and promoted Sustainable Development Goals, as shown in **Figure 7-23**.

Renewable Resources Sustainable development focuses on careful use of renewable ecosystem services. A **renewable resource** can be produced or replaced by a healthy ecosystem. A single southern white pine is one example of a renewable resource because a new tree can grow in place of an old tree that dies or is cut down. Another example is drinkable water. In many places, drinking water is provided naturally by streams, rivers, and lakes, and it is filtered by forest soils and wetlands. But if human-caused environmental changes impact ecosystem function, water quality may fall. If that happens, cities and towns must pay for mechanical or chemical treatment to provide safe drinking water. Electricity generated from wind farms, like the one shown in **Figure 7-24**, or solar power is also a renewable resource.

Nonrenewable Resources If natural processes cannot replenish resources within a reasonable time, they are considered to be **nonrenewable resources**. Fossil fuels such as coal, oil, and natural gas are nonrenewable resources formed from buried organic materials over millions of years. When existing deposits are depleted, they are gone.

Innovation and Resilience

Human intelligence and creativity related to science have gotten us out of a lot of scrapes! Still, technology won't automatically solve our problems, unless it is guided by sustainable goals. We need constant innovation—new ideas and new engineering solutions that provide a necessary service at a reasonable cost. Solar generation of electricity, for example, was technically possible more than twenty years ago. Back then, however, solar panels were much too expensive for individual consumers to afford them. But a steady stream of engineering and manufacturing innovations has dramatically lowered the price of this technology. Now, solar panels are mass-market products that are widely installed on both commercial buildings and private homes.

Ecologists and many government agencies—including the U.S. military—recognize that life in the Anthropocene involves unpredictability. Some of that unpredictability involves loss of ecosystem services from biodiversity loss. More unpredictability will result from increased frequency of droughts in some places. And even more unpredictability will result from increasing frequency of other extreme weather events, such as hurricanes and floods.

That's why sustainable development must include **resilience,** which is the ability to deal with change and move on. ***Sustainable development must be flexible enough to survive environmental stresses like droughts, floods, storms, and heat waves or cold snaps.*** When hurricanes hit the United States, for example, they can cause some loss of life and significant loss of property. But our cities are resilient enough (or at least they have been so far) to deal with the damage and rebuild. When serious hurricanes hit places like Haiti or Honduras, for example, those much less resilient countries experience major loss of life and widespread destruction that is difficult to handle on their own.

INTERACTIVITY

Figure 7-24

Renewable Energy

The electricity produced by these wind turbines is considered a renewable resource. The wind energy that turns the turbines cannot be used up.

INTERACTIVITY

Investigate how biogas is made from the breakdown of wastes.

HS-LS2-7, HS-LS4-6 HS-ETS1-1, HS-ESS3-4, HS-ESS3-5

LESSON 7.4 Review

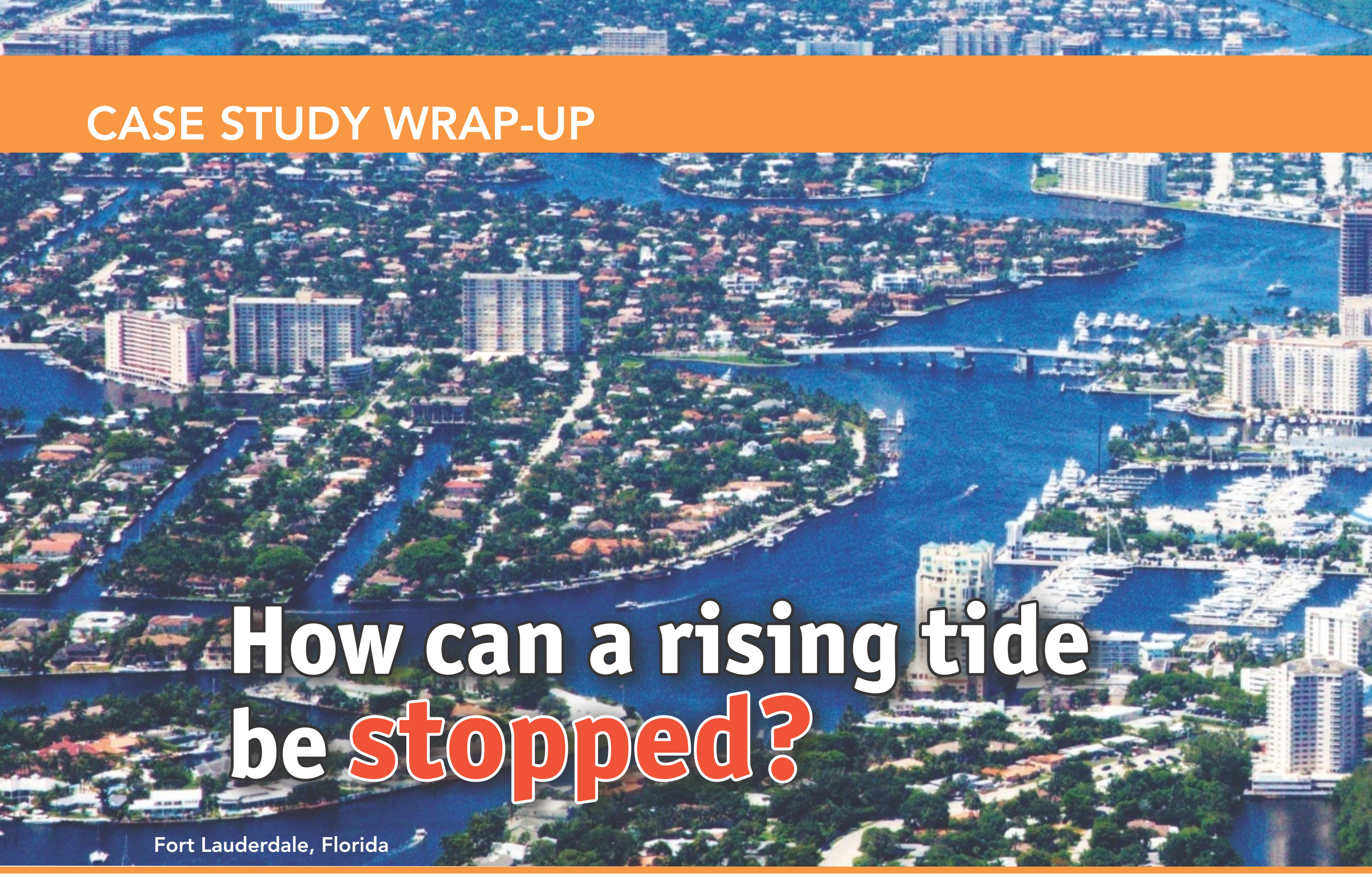
KEY QUESTIONS

1. How are resources used in sustainable development?
2. Why is resilience important for sustainable development?

CRITICAL THINKING

3. **Identify Variables** City planners are deciding where to build a new stadium. Choices include the city center, an old farm just outside the city, and wetlands by a river. To make a decision that promotes sustainable development, what variables should the planners identify?

CASE STUDY WRAP-UP



How can a rising tide be stopped?

Fort Lauderdale, Florida

Rising seas threaten coastal areas around the world. Southern Florida is uniquely at risk because three quarters of its population lives densely packed along its low-lying coasts.

HS-ETS1-1, CCSS.MATH.HS.MP.2, CCSS.ELA-LITERACY.RST.9-10.1, CCSS.ELA-LITERACY.RST.9-10.2, CCSS.ELA-LITERACY.WHST.9-10.1, CCSS.ELA-LITERACY.WHST.9-10.2, CCSS.ELA-LITERACY.WHST.9-10.7, CCSS.ELA-LITERACY.WHST.9-10.8

Make Your Case

Human-caused global change creates a wide variety of challenges for people everywhere. Some challenges can be addressed at a local level, but others require international cooperation on a global scale.

Develop a Solution

1. **Conduct Research** Explore the goals, accomplishments, and limitations of a regional group, such as the Southeast Florida Climate Compact, the Will Steger Foundation's Climate Generation, or the Totonicapán reforestation project guided by EcoLogic Development fund. Your research should include verifiable scientific facts and expert scientific opinions.
2. **Construct an Argument** Evaluate successes and challenges you perceive in the work of your chosen organization. Apply that information as you develop and propose a course of action to address related issues in your local area. What are the costs and benefits of action compared with those of inaction? Write a persuasive, evidence-based argument in support of your ideas.

Society on the Case

Flooded Lands

Changes in global systems have many causes and many effects. Scientists and governments are struggling to understand global change and what it means to humanity everywhere.

The effects of sea level rise are among the easiest to see today and to predict. Americans are learning about challenges faced by Miami, New Orleans, and parts of North Carolina. As real and as serious as those problems are, they pale in comparison to threats faced by many millions of people in low-lying parts of Asia. The coastal city of Shanghai, China, currently home to 24 million people, is built on a low, flat river delta. During this century, between 18 and 40 million people in that city alone could be displaced by rising seas! Bangladesh could lose not only equivalent parts of coastal cities, but millions of hectares of fertile farmland as well.

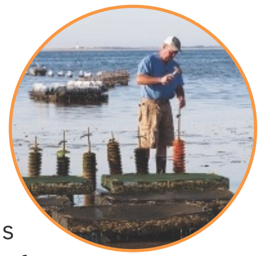
In addition, fresh water for drinking and irrigation is threatened in many places. In some regions, such as southern Florida, salt water from rising seas is already affecting drinking water supplies. In parts of the southwestern United States, southern California, and much of Mexico's Central Valley, a mix of climate change, population growth, and increased irrigation is causing more frequent and more severe water shortages. Rising to these challenges will require data from the best available science, inputs from economists and engineers, and responsible government action.

Careers on the Case

Work Toward a Solution

Scientists and engineers are working on ways to cope with global change. Jobs in many fields are being created by rising seas, more variable weather, and changes in precipitation.

Aquaculture Farmer



For hundreds of years, people have harvested fish and other seafood directly from the sea. Today, farmers are also raising marine animals like other livestock. This type of farming is called aquaculture. Natural stocks of commercial fish species might decline sharply due to global climate change, overfishing, or other causes. Aquaculture could help replace them.

VIDEO

Watch this video to learn about other careers in biology.

hhmi | BioInteractive

Lesson Review

Go to your Biology Foundations Workbook for longer versions of these lesson summaries.

7.1 Ecological Footprints

Humanity's ecological footprint—which includes the use of resources such as energy, food, water, and shelter, and the production of wastes such as sewage and greenhouse gases—is measurable. By some calculations, the average American has an ecological footprint four times larger than the global average.

The Age of Humans, or the Anthropocene, began with the onset of the Industrial Revolution in the 1800s and accelerated beginning in the 1950s with technological developments in mining, farming, and medicine. Today, human activities are the single most powerful force for global change. People live in anthromes, or anthropogenic biomes, of their own creation.

- ecological footprint
- anthrome

Interpret Visuals Add labels to the different parts of the visual and explain how they describe an ecological footprint. Some labels may be used more than once.

Labels: agriculture, housing, cars, garbage, cattle, cropland, sewage treatment, electricity, coal-burning power plant, travel, fishing, agricultural runoff

7.2 Causes and Effects of Global Change

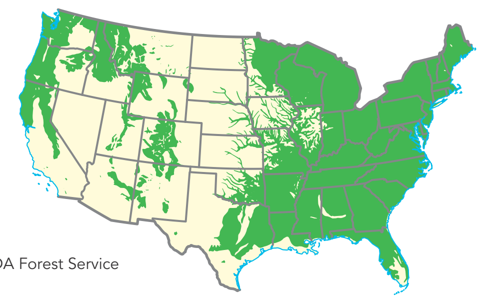
Human activities affect global environments and systems through pollution, land use, and interaction with other species.

Pollutants, harmful materials created as a result of human activity and released into the environment, drive global changes in air quality and temperature averages. Burning fossil fuels increases concentrations of greenhouse gases, which contribute to global warming. This warming leads to climate change.

Biological magnification of pollutants such as lead, mercury, PCBs, and DDT has produced serious toxic effects on human and animal populations. Other harmful practices, such as deforestation and habitat fragmentation, have contributed to the loss of biodiversity of animal and plant populations.

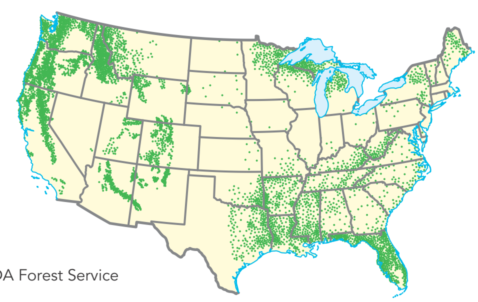
- climate change
- global warming
- deforestation
- monoculture
- invasive species
- pollutant
- ozone layer
- smog
- biological magnification

1620



Source: USDA Forest Service

1920



Source: USDA Forest Service

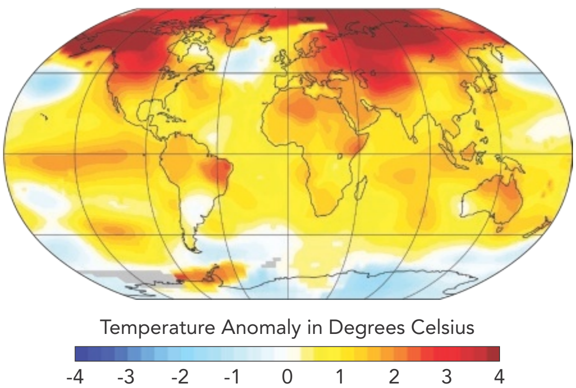
Compare How did the area covered by primary forest in the continental United States changed over 300 years?

7.3 Measuring and Responding to Change

Scientific research can have a positive impact on the global environment by recognizing a problem, researching the problem to determine its cause, and then guiding changes. Correcting the damage to the ozone layer from the use of chlorofluorocarbons is a case in point.

The problem of climate change is a complicated issue, but data have been gathered, analyzed, and reviewed, indicating that Earth is warming faster than at any time in recorded history. Shifts in temperate zones and rising sea levels are among the effects that must be addressed. Changing patterns of precipitation in agricultural areas has immediate consequences on food production, as well as long-term effects on entire ecosystems.

Global Mean Surface Temperature (GISS)
January–June 2016



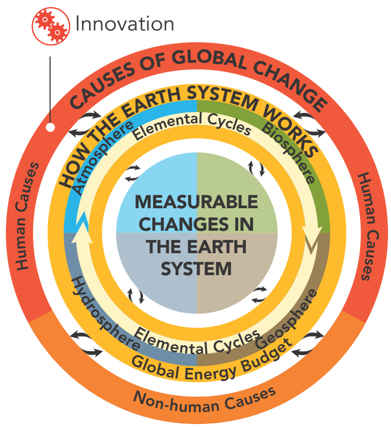
Source: NASA/GISS

Interpret Data What patterns are observed in these data?

7.4 Sustainability

Using resources in a way that preserves environmental resources is called sustainable development. Scientific, economic, and political action must intertwine to support the needs of sustainability. The focus is on careful use of renewable resources in innovative ways to replace older technologies based on the consumption of nonrenewable resources. Addressing unpredictable events, such as devastation from fires or floods, requires flexibility and resilience.

- sustainable development
- renewable resource
- nonrenewable resource
- resilience



Connect to Society Describe two examples of how innovations, guided by sustainable development goals, are being used to decrease the effects of human activity on the Earth system. Identify and explain which system processes and phenomena in the UGC model are affected by these innovations.

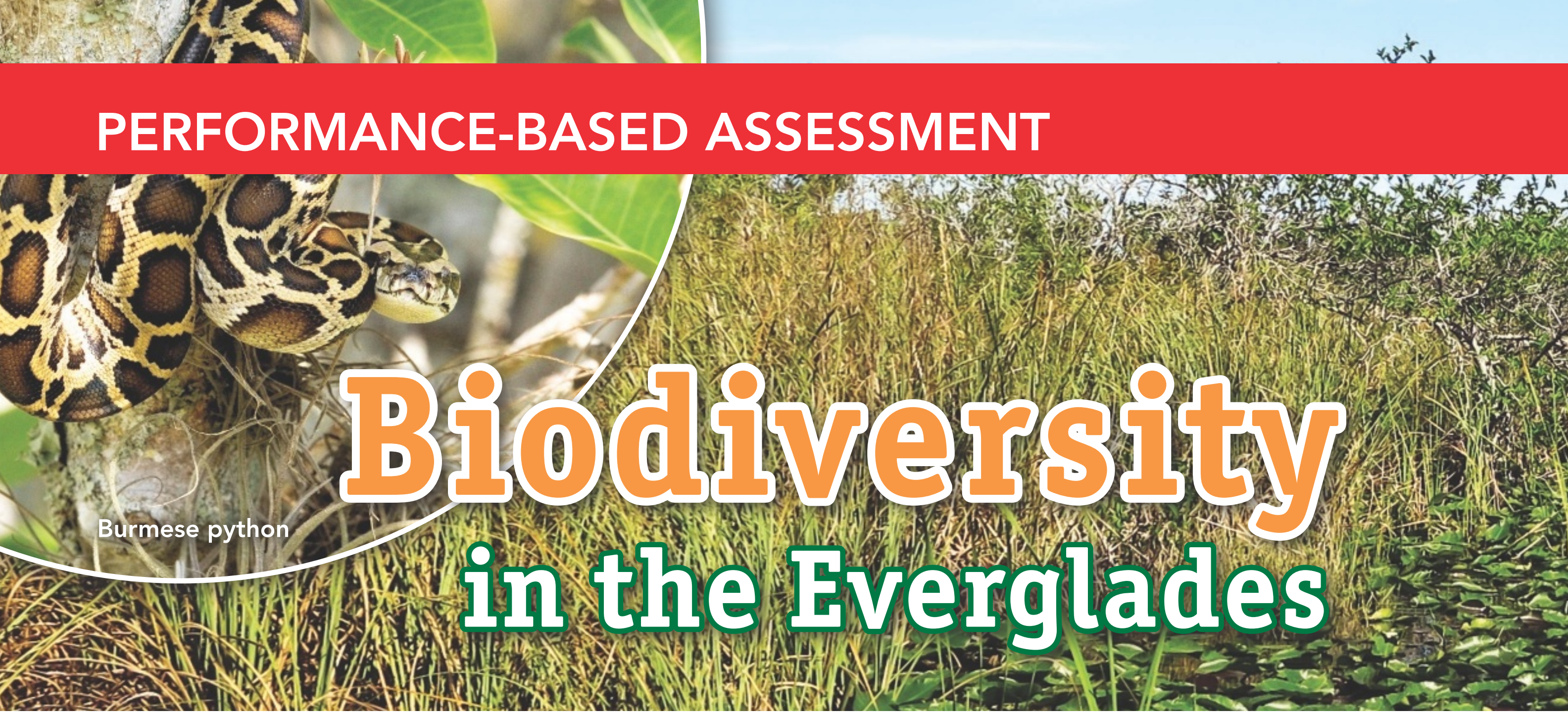
Organize Information

Complete the T-chart by giving a brief explanation of the problems associated with each issue

Issue	Problem
Acid rain	1.
Nitrogen enrichment	2.
Ocean acidification	3.
Ozone layer	4.
DDT	5.

PERFORMANCE-BASED ASSESSMENT

Biodiversity in the Everglades


Burmese python

Design a Solution

HS-LS2-7, HS-ETS1-2, HS-ESS3-3, HS-ESS3-4, HS-ESS3-6

STEM Florida residents once dismissed the value of the Everglades, the marshy wetlands that covered much of the southern half of the state. Ideas began changing in 1947, when Marjory Stoneman Douglas published the book *The Everglades: River of Grass*. Douglas described the rich biodiversity of the Everglades, as well as the role of the wetlands in providing clean water for the region.

The Everglades once covered almost 3 million acres of southern Florida. Now it has shrunk to about a third of that size. Much of the Everglades is part of a national park, where human activities are limited and wildlife is protected. However, more than 20 Everglades species are classified as endangered, and many more are threatened. Dense urban areas and commercial farms surround the Everglades on all sides—and they have proven to be disruptive neighbors.

The following bullet points list some of the ways that human activities have threatened the Everglades environment and its biodiversity. As you read the list, relate each entry to the rapid increase in Florida's human population. One hundred years ago, Florida was home to about 1 million people, most of whom lived far away from the Everglades in the northern part of the state. In 1980, the population shifted south and had grown to 10 million. Today, the population is over 20 million—and still increasing.

- **Water Control** The Everglades depends on a steady supply of fresh water that flows slowly from north to south. Today, canals and dams divert water for human uses and to prevent flooding. Much of the original Everglades has already been drained for new farms and housing developments.
- **Fertilizer** Runoff from farms has been adding fertilizer to the Everglades water supply. The fertilizer supports the growth of plants such as cattails and duckweed that otherwise would not grow in the Everglades. The fertilizer also supports harmful algal blooms.
- **Invasive Species** Through carelessness or ignorance, human actions have introduced all sorts of new species into the Everglades, some of which have proved invasive. The Burmese python is now competing with the alligator to be the top predator of the Everglades. Invasive plants, such as the Brazilian pepper and Australian pine, are now displacing native species.

Fields of crops, such as the sugar cane shown here, now take up much of Florida's land.

In this assessment, you will design, evaluate, and refine a solution for reducing the impact of human activities on the Everglades environment and its biodiversity.

1. **Conduct Research** Find out more about the biodiversity of the Everglades ecosystem and the threats to it. Also research how government agencies, private organizations, and individual citizens have been working to protect the Everglades, and what the results of these actions are.
2. **Define the Problem** In your own words, define one or more of the problems in the Everglades ecosystem that human activities have caused.
3. **Design Possible Solutions** Work in a small group. With your group members, propose ideas for solutions to one or more of the problems that you identified. Your ideas might include new laws to regulate water use, volunteer brigades to combat invasive species, or research into new farming practices that reduce fertilizer in runoff.
4. **Evaluate a Solution** Choose one of the potential solutions to develop further. Identify criteria for evaluating the solution, such as its potential effectiveness in improving the Everglades and protecting biodiversity. Also identify the costs and other constraints of the solution. Conduct additional research to evaluate the solution according to these criteria and constraints.
5. **Refine a Solution** Based on your research, refine your original proposal. Present your solution in a written or oral report, or as a computer presentation. Your report should include the following information:
   - a change to the Everglades or its biodiversity, and an explanation of the problems that this change could cause or is causing
   - the details of your proposed solution to the problems
   - an evaluation of the benefits and drawbacks of the solution

Share your report with classmates.

ASSESSMENT

KEY QUESTIONS AND TERMS

7.1 Ecological Footprints

HS-LS2-7

1. The total area of land and water ecosystems an individual needs to obtain food, shelter, home heating, travel, and waste absorption is called
   a. a land-management plan.
   b. an environmental problem.
   c. an ecological footprint.
   d. a measure of diversity.
2. The Anthropocene is said to have begun
   a. with the American Revolution.
   b. with the Industrial Revolution.
   c. in the 1950s.
   d. at the end of the twentieth century.
3. Which of the following would have the LEAST adverse effect on the environment?
   a. clearing a forested area outside of a city to build houses
   b. building apartments at the site of an abandoned factory in the city
   c. building a neighborhood in a meadow at the edge of the city
   d. filling a wetland area and building oceanfront condominiums
4. How does an anthrome differ from a biome?
5. How does the average American's environmental footprint compare with the global average?
6. Why is the current era called the Anthropocene?

7.2 Causes and Effects of Global Change

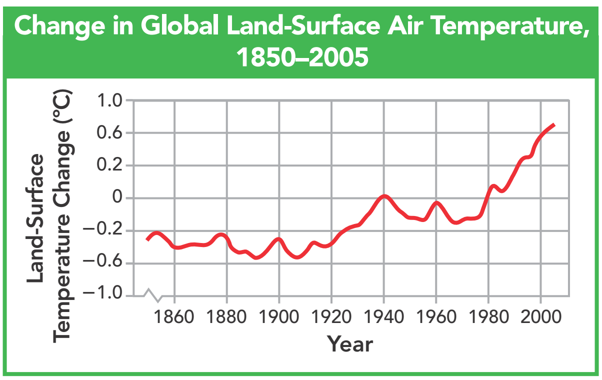
HS-LS2-2, HS-LS2-7, HS-LS4-6, HS-ESS2-6, HS-ESS3-6

7. What term describes measurable long-term changes in averages of temperature, clouds, winds, precipitation, and the frequency of extreme weather events?
   a. climate change
   b. global warming
   c. monoculture
   d. biological magnification
8. All of the following cause global change EXCEPT
   a. biological magnification of toxic compounds.
   b. habitat preservation.
   c. habitat fragmentation.
   d. deforestation.
9. Introducing an exotic species to an environment can
   a. improve soil fertility.
   b. cause biological magnification.
   c. cause native species to die out.
   d. increase crop yields.
10. DDT was banned for use in the United States because over the long run it is
    a. a deadly insecticide.
    b. toxic to herbivores.
    c. subject to biological magnification.
    d. poisonous to soil bacteria.
11. Which pollutant is the major cause of global change?
12. What are the advantages and disadvantages of monoculture farming?
13. What steps can be taken to reduce the problem of smog in urban areas?

7.3 Measuring and Responding to Change

HS-LS2-7, HS-ETS1-1, HS-ESS3-4, HS-ESS3-5, HS-ESS3-6

14. Study the following graph:



    What problem did ecologists identify as a result of studying graphs like this one?
    a. habitat fragmentation
    b. the hole in the ozone layer
    c. deforestation
    d. global warming
15. The major cause of global warming is
    a. sun flare pollution.
    b. biological magnification.
    c. monoculture farming.
    d. burning fossil fuels.

16. Air and water pollution have been reduced by
    a. using fossil fuels in factories.
    b. raising more cattle for food.
    c. using only unleaded gasoline.
    d. increasing biological magnification.
17. What was the effect on the environment of banning chlorofluorocarbons?
18. In what ways does global warming affect food production?
19. Identify some areas most likely to be impacted by the effects of global warming.

7.4 Sustainability

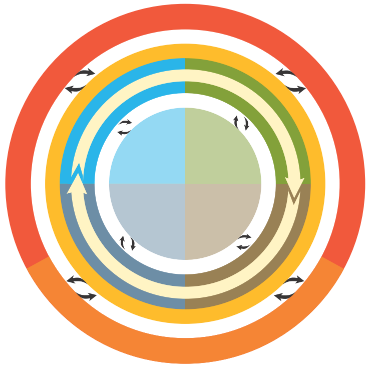
HS-LS2-7, HS-LS4-6, HS-ETS1-1, HS-ESS3-4, HS-ESS3-5

20. Which of the following is a renewable resource?
    a. coal c. oil
    b. trees d. natural gas
21. Using resources in ways that do not cause long-term environmental degradation is called
    a. sustainable development.
    b. monoculture.
    c. resilience.
    d. deforestation.
22. The ability of a city to rebuild after a natural disaster such as a hurricane is called
    a. reforestation. c. resilience.
    b. recycling. d. resourcing.
23. How can solar energy contribute to a sustainable development program?
24. What is the scientific importance of the United Nations Sustainable Development Goals?
25. How does resilience complement sustainability?

CRITICAL THINKING

HS-LS2-2, HS-LS2-7, HS-LS4-6, HS-ETS1-1, HS-ESS3-3, HS-ESS3-4, HS-ESS3-5, HS-ESS3-6

26. **Evaluate a Solution** The Montreal Protocol banning the use of CFCs was put into force in 1989. Explain the long-term goals of the Montreal Protocol.
27. **Analyze** How have human activities led to changes in biodiversity?
28. **Construct an Explanation** Recall that purifying water is an ecosystem service. How can human activities disrupt this service?
29. **Use Models** Throughout the last five chapters, we have added Earth system processes and phenomena to the Understanding Global Change model. Choose two topics from the Causes of Global Change category in this model. Using words and arrows, explain how these Causes of Change affect processes in the How the Earth System Works and Measurable Changes in the Earth System.



30. **Use Visuals** The photo shows purple loosestrife, a nonnative species that grows in marshes and other wetlands. Describe how purple loosestrife can result in the loss of biodiversity. Propose a solution to mitigate the adverse effects of loosestrife on the environment.

31. **Use Computational Models** What trends in average global temperature do computational models predict if greenhouse gas emissions continue to increase as they have in recent years? Propose a solution to decrease the rise in average global temperature. Identify criteria and constraints for your solution.
32. **Evaluate Claims** Scientists have come to a consensus that Earth's climate is changing. Cite evidence to support this claim, and explain how this change in climate affects populations.
33. **Evaluate a Solution** How would decreasing the burning of fossil fuels help reduce acid rain?

CROSSCUTTING CONCEPTS

34. **Cause and Effect** How has the burning of fossil fuels contributed to global climate change?

35. **System and System Models** Why is it important to include oceans, the atmosphere, and human activities when developing a useful model of ocean acidification?

36. **Stability and Change** How could decisions that people make today determine whether global systems will change or remain stable in the future? Cite evidence and a specific example to support your answer.

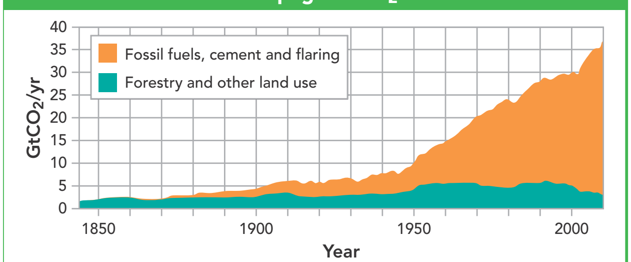
MATH CONNECTIONS

Analyze and Interpret Data

CCSS.MATH.CONTENT.MP2, CCSS.MATH.CONTENT.MP4, CCSS.MATH.CONTENT.HSS.IC.B.6

Use the graph to answer questions 37–39.

Global Anthropogenic CO_2 Emissions



Quantitative information of CH_4 and N_2O emission time series from 1850 to 1970 is limited.
Source: Adapted from Intergovernmental Panel on Climate Change.

37. **Interpret Graphs** How have global anthropogenic (human-caused) CO_2 emissions changed since 1850? What is the main cause of this change?

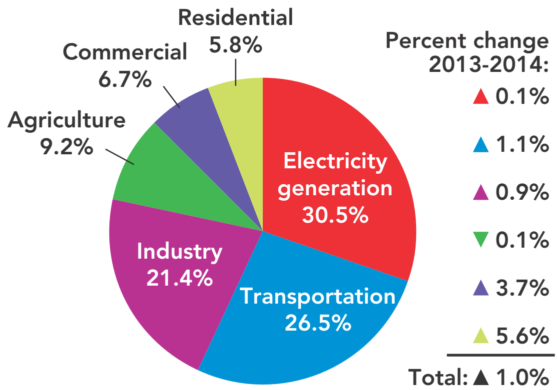
38. **Evaluate Solutions** If humans reduce CO_2 emissions in the future and reverse the trend shown in the graph, does this solve the problem of global warming?

39. **Design a Possible Solution** What actions or policies do you recommend to reverse global CO_2 emissions? Describe the value of your recommendations.

The following circle graph describes the sources of greenhouse gases from the United States. Use the circle graph to answer questions 40–43.

U.S. Greenhouse Gas Emissions by Economic Sector, 2014

Emissions in million metric tons of carbon dioxide equivalents



Source: U.S. EPA's Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2014.

40. **Analyze Graphs** Identify the three main sources of greenhouse gas emissions.

41. **Analyze Data** Either directly or indirectly, do you contribute to each of the sources of greenhouse gas emissions shown in the graph? Explain.

42. **Infer** From 2013 to 2014, which sector had the greatest percentage increase in greenhouse gas emissions? Propose a possible explanation.

43. **Design a Solution** Suppose you are asked to propose a plan to reduce the emissions of greenhouse gases. On which form of transportation would you concentrate your efforts, and why?

LANGUAGE ARTS CONNECTION

Write About Science

CCSS.ELA-LITERACY.WHST.9-10.2, CCSS.ELA-LITERACY.WHST.9-10.4

44. **Produce Clear Writing** Write a paragraph that defines your ecological footprint.

Read About Science

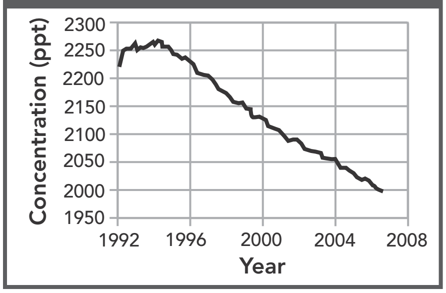
CCSS.ELA-LITERACY.RST.9-10.7

45. **Integrate With Visuals** Choose one of the line graphs from the chapter and review the text passage that accompanies it. How does the graph illustrate the process discussed in the passage?

END-OF-COURSE TEST PRACTICE

1. Evaluate the following activities. Which activity is MOST LIKELY to have the smallest impact on environmental systems?
   A. using more land to grow corn that is used to produce fuel
   B. using land to create a national park
   C. building a dam for energy production
   D. building new housing in an area far from a city
   E. building new highways so automobiles can travel faster

2. Legislation was introduced in 1987 to ban the use of compounds that were depleting the ozone layer. The graph below shows the levels of halogens in the atmosphere for several years after the legislation was passed.



   What conclusion can you draw from this graph?
   A. The size of the ozone layer decreased during this time period.
   B. The concentration of ozone in the upper atmosphere increased during this time period.
   C. The concentration of halogens in the atmosphere decreased during this time period.
   D. The size of Antarctica below the ozone layer decreased during this time period.
   E. The concentration of heavy metals in the atmosphere decreased during this time period.

3. Which of the following could be a solution to help reverse a loss of biodiversity?
   A. habitat fragmentation
   B. reducing the size of the ozone layer
   C. increased use of monocultures
   D. reforestation
   E. invasive species

4. Fossil fuels are commonly used as an energy source for transportation vehicles. Burning fossil fuels has led to more carbon dioxide in the atmosphere and dissolved in seawater. Which of the following describes how burning fossil fuels is MOST LIKELY to impact marine organisms?
   A. Increased levels of carbon dioxide in seawater would increase the rate of photosynthesis in marine plants.
   B. Dissolved carbon dioxide in seawater would cause an increase in shellfish populations due to strengthened skeletons.
   C. Increased levels of carbon dioxide in seawater would cause ocean acidification and weaken corals.
   D. Dissolved carbon dioxide in seawater would cause invasive species to out-compete native species.

ASSESSMENT

For additional assessment practice, go online to access your digital course.

If You Have Trouble With...

Question	1	2	3	4
See Lesson	7.1	7.2	7.2	7.2
Performance Expectation	HS-LS2-7	HS-LS2-7	HS-ESS3-4	HS-ESS3-6