Key Terms
global warming
desertification
deforestation

7.3 Indicators and Effects of Climate Change

global warming an increase in global average temperature

The largest single indicator of climate change has been **global warming**—the increase in the average temperature of the atmosphere and oceans that has been measured over the past 100 years. The rate of increase has accelerated since the 1960s. This warming is an average for the entire planet, which means that some regions of Earth have experienced more warming than others and some have actually grown cooler during this period. The actual amount and rate of warming are also uncertain due to natural fluctuations from year to year and sources of bias resulting from where measurements have been taken. However, indirect indicators of warming, such as melting glaciers, support the evidence from direct measurements of temperature. In fact, all of the events or conditions described in this section are influenced or caused by changes in global temperatures.

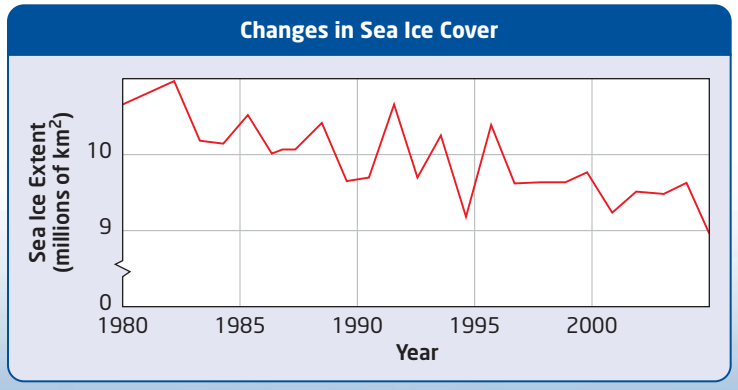

Figure 7.20 The surface area of Arctic sea ice has been shrinking since the first satellite measurements in the late 1970s.

Changes in Polar and Glacial Ice

Satellite measurements have shown that large volumes of ice in Greenland and the Antarctic have been melting at higher rates in recent years, as shown in **Figure 7.20**. For example, the overall loss of mass in the West Antarctic ice sheet has been approximately 65 km^3 per year. That amount of melting releases enough water to raise sea levels by about 0.16 mm per year. The process that forms ice sheets is complex, and some ice sheets thicken while others grow thinner. However, the general trend has been to an overall shrinking of Earth's ice cover.

Impacts of Melting Ice

Apart from raising sea levels, melting ice affects the habitat of animals such as seals and polar bears. For example, polar bears such as the one shown in **Figure 7.21**, depend on large areas of sea ice over which they hunt their prey. As warmer temperatures melt sea ice and transform the arctic biome, polar bears in some parts of their range may be starving or ranging farther to find food. In 2007, the Wildlife Conservation Society (WCS) launched an initiative called "Warm Waters for Cool Bears." Under this initiative, landscape ecologists are studying satellite and weather data collected over 30 years to identify how sea-ice habitats are changing. This information will help scientists and policy makers decide what areas to protect as polar bear habitats.

The culture and lifestyle of Canada's Inuit population is closely tied to the environment of the Arctic and its wildlife. The traditional lifestyle of Inuit peoples involves travelling and hunting on sea ice. However, thinning and disappearing sea ice has made travelling treacherous and may make hunting for food or income more unpredictable. Political groups like the Inuit Circumpolar Council have expressed concern over the need to take action on global warming to reduce its impact on their communities. Programs, such as the Igliniit Project, have been initiated to record the weather conditions and observations made by Inuit hunters and travellers in an attempt to study how the ice is changing, and to gauge the effects of changing ice on Inuit communities.

Study Toolkit

Making Inferences A table like the one shown on page 268 can be used to organize information about causes and effects. Use this strategy to make an inference about how global warming affects polar bears.

Go to **scienceontario** to find out more

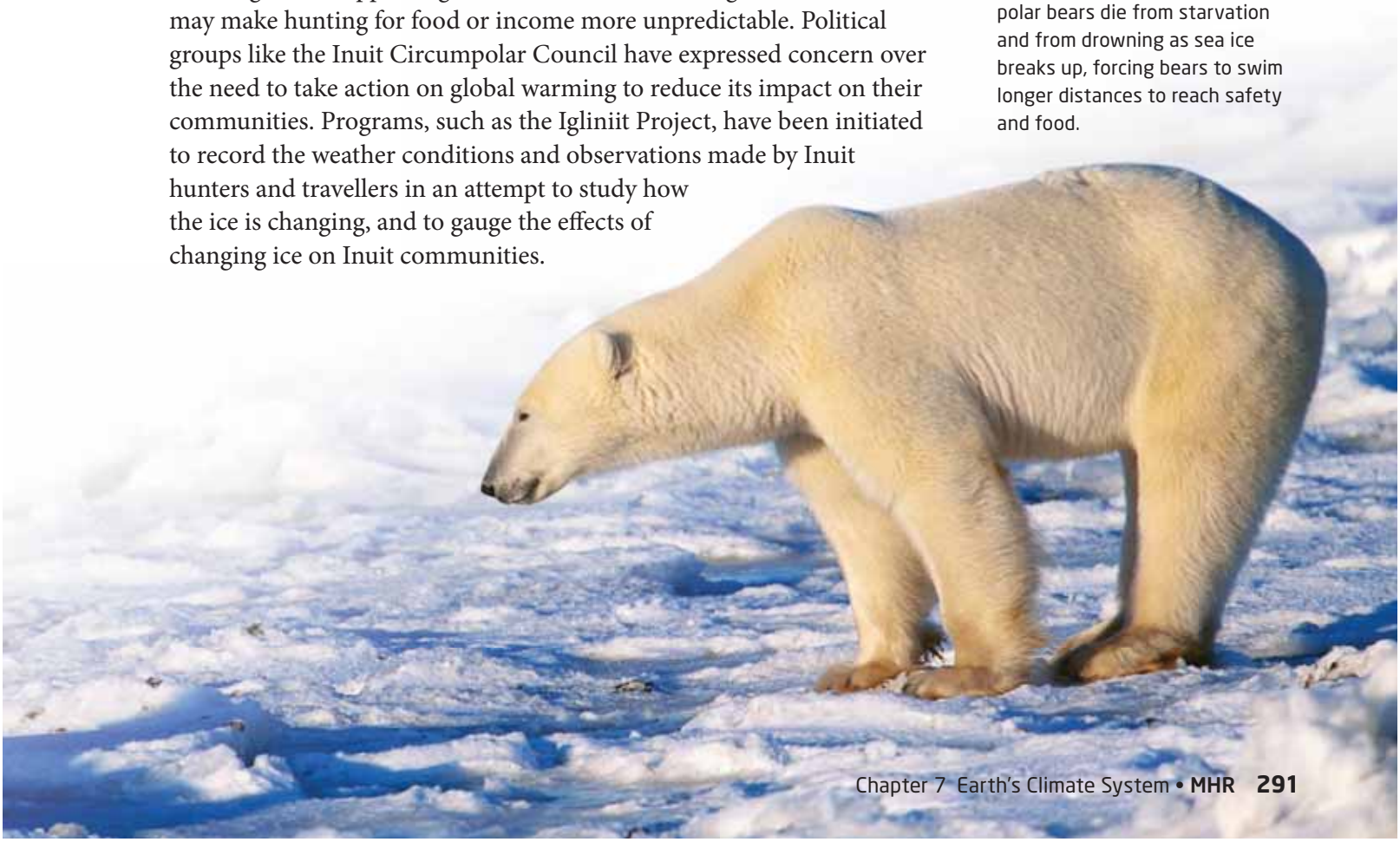

Figure 7.21 Every year, more polar bears die from starvation and from drowning as sea ice breaks up, forcing bears to swim longer distances to reach safety and food.

Making a Difference

BJ Bodnar developed a connection to nature while growing up on a farm. He uses this connection to inspire other people to confront climate change issues. When BJ was 14, he became the youngest member of the Saskatchewan Provincial Youth Advisory Committee and helped create Saskatchewan's Provincial Green Strategy. He has also served as Ambassador to the Al Gore Climate Change Symposium for Youth.

BJ has joined expeditions to the Canadian High Arctic, the Russian Arctic, and Antarctica. In 2008, BJ was named one of Canada's Top 20 Under 20 by Youth in Motion. He is studying political and international studies at the University of Saskatchewan.

If you were an advisor to the provincial government, what indicators of climate change would you focus on? Explain your answer.

Rising Sea Level and Ocean Acidity

Oceans are a major part of Earth's climate system, so any change in the oceans is a cause for concern. Climate scientists are especially concerned about sea level and ocean acidity. These indicators of climate change are described in **Table 7.2** on the next page.

The average sea level has risen between 10 and 15 cm over the past 100 years. Scientists project that the melting of ice in glaciers and icecaps outside of Greenland and Antarctica, including the approximately 150 000 km^2 of ice in Canada, could cause global sea levels to rise by 20 to 40 cm within the next 100 years. **Figure 7.22** shows which areas of the world would be submerged as sea level rises. However, the influence of tides, ocean currents, and prevailing winds will produce greater impacts in some areas and reduce impact in others.

As parts of the world's oceans become warmer, changes in ocean pH and in sea level have occurred. Research indicates that between 1751 and 2004, surface ocean pH dropped from approximately 8.25 to 8.14. Coral reefs that form in environments that are naturally high in carbon dioxide are poorly formed and are not as stable as those in waters that contain less dissolved carbon dioxide.

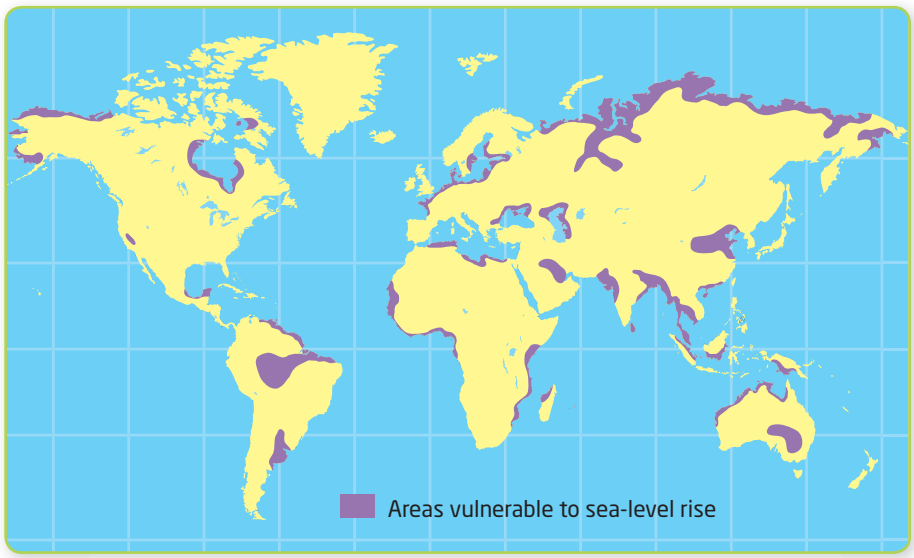

Figure 7.22 Rising sea level is likely a result of global warming. Many coastal areas and island nations would be flooded by relatively small changes in sea level.

Table 7.2 Effects of Climate Change on Earth's Oceans

Indicator	Cause	Effects
Rising sea level	About half of this increase is due to the observed melting of glaciers and icecaps. The other half is a result of the thermal expansion of seawater due to increased temperature.	As sea level rises, more land will be covered by water. Many of the world's largest cities are located in coastal regions, so large populations of people will be displaced by rising seas.
Rising ocean acidity	Scientists estimate that the oceans have absorbed about half of all carbon dioxide produced from fossil fuel emissions over the past 200 years. Some of the dissolved gas forms carbonic acid, which lowers the pH of the water. Lower pH means that the water is more acidic.	Rising acidity threatens the ability of corals and other organisms to build shells and hard skeletons and the ability of fish and plankton to reproduce. The success of commercial fishers who supply food to humans may also be affected, and low-lying islands and coastal areas would be more vulnerable to storms.

Activity 7-4

Acidity and Coral Reefs

How does ocean acidity affect living things? In this activity, you will model the effects of acidic ocean water on shells.

Safety Precautions

- Alert your teacher if you are allergic to eggs.
- Wash your hands thoroughly after handling acids.

Materials

- 3 glass jars or 50 mL beakers
- 20 mL water
- 20 mL vinegar
- 20 mL soft drink
- 3 pieces of chalk or eggshell
- graduated cylinder
- tongs

Procedure

1. Pour 20 mL of water into a glass jar. Pour 20 mL of vinegar into a second jar. Pour 20 mL of soft drink into a third jar.
2. Observe the surface of the pieces of chalk or eggshell. Record your observations.
3. Carefully place one piece of chalk or eggshell in each of the three glass jars. Observe and record any reactions.
4. Leave the chalk or eggshell in the jars overnight.

Eggshells contain calcium carbonate, and soft drinks are acidic.

5. The following day, use tongs to remove the chalk or eggshell from each jar.
6. Observe the surface of each piece of chalk. Record your observations.

Questions

1. What happened to the surface of the chalk or eggshell in each solution?
2. Which liquid has the highest acidity–water, vinegar, or soft drink? Explain your answer.
3. What effect would rising acidity have on the organisms that make shells from calcium carbonate?

Figure 7.23 Deer mice are carriers of hantavirus.

Climate and Health

Climate is closely connected with health—not only with the risk of disease and infections, but also the risk of injury or death due to extreme weather, such as heat waves, floods, tornadoes, lightning strikes, and snowstorms. Some of the most serious diseases that affect humans are carried by insects, rodents, birds, and other animals. For example, hantavirus is carried by mice, such as the deer mouse shown in **Figure 7.23**. Outbreaks of this infection—as well as of lyme disease, malaria, and plague—seem to increase during periods of higher temperatures. The risk of waterborne diseases also rises as climate change affects rainfall and temperature. Waterborne diseases are caused by microscopic organisms that live in water supplies.

Increasing temperatures affect the amount of dust in the air, the growth of mould, and the release of pollen by many plants. All of these substances may act as allergens and may trigger asthma attacks in some people. Scientists are researching how climate changes may contribute to an increase in the number of smog days in Ontario and elsewhere in Canada. As the air quality worsens, people who have allergies or other respiratory difficulties may have to reduce their outdoor activities. In addition, people who have respiratory problems may require medical attention, which increases health-care costs.

STSE Case Study

The Walkerton Water Tragedy

The largest waterborne multi-bacterial outbreak ever to occur in Canada happened in Walkerton, Ontario, in May of 2000. Unusually heavy rain fell for five days in a row, which caused the ground to become saturated. Run-off from a nearby farm entered one of the wells that supplied the town's drinking water. The run-off contained pathogens including *E. coli*. These pathogens made 2300 people seriously ill and killed seven people. The intense rain was the cause of the outbreak, but a number of problems combined to create the disaster. These problems included sloppy water testing and poor reporting by the workers at the water treatment facility.

Waterborne diseases are a significant health risk for humans around the world. These diseases, including giardiasis and cryptosporidiosis, occur when humans and other animals ingest bacteria, viruses, and other parasites by drinking contaminated water.

Heavy rains near farm pastures can carry protozoans and bacteria, such as the *E. coli* in the inset photo, from cow manure into drinking water supplies.

Changing Wind and Precipitation Patterns

Changes in heat distribution over Earth's surface have led to changes in wind patterns. The speed, frequency, and direction of winds over Earth's surface have fluctuated unpredictably for several years. Researchers believe that unusual wind patterns have helped increase the melting of ice in the Arctic.

High temperatures increase the rate of evaporation. When warm, moist air rises and cools in the upper atmosphere, it produces rain or snow. Since 1948, average annual temperatures across Ontario have increased by as much as 1.4°C. Average annual precipitation has also increased over this period, as shown in **Figure 7.24**. The total number of days per year on which precipitation falls has also increased. In the northern part of the province, a significant increase has occurred in the number of snowfalls and the quantity of snow during autumn.

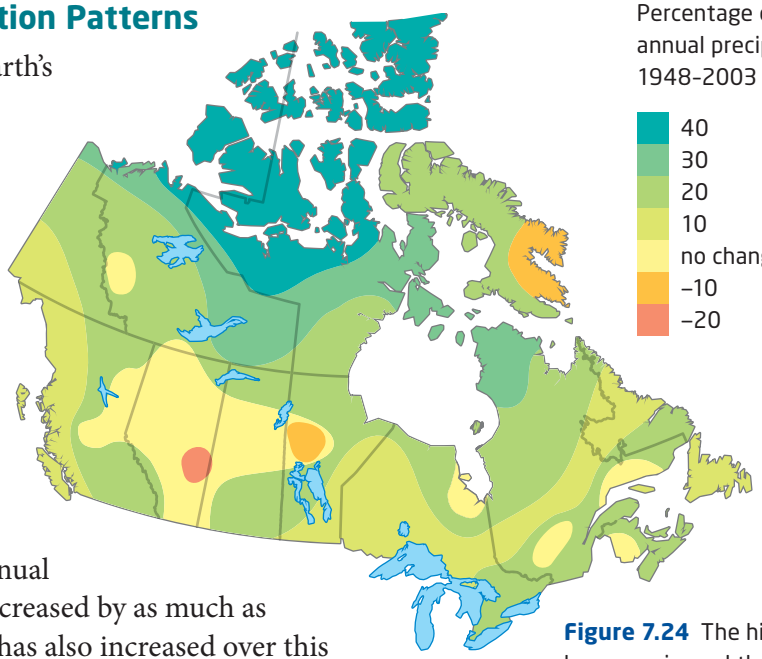

Figure 7.24 The high Arctic has experienced the largest increase in precipitation since 1948, while regions of southwestern Canada have experienced little change in precipitation rates.

As Global Warming Increases

- precipitation and flooding increase
- run-off from streets and fields increases
- storm water systems and sewage systems overflow
- animal waste, fertilizers, and raw sewage can be diverted into drinking water reservoirs
- parasites flourish in drinking water
- waterborne disease increases

Improved Safety Net

The government responded to the Walkerton tragedy by increasing the safety measures around public drinking water. For example, water testing and inspection processes were improved. The training and licensing of water system workers were also improved and toughened. These changes and regulations have been strongly enforced.

However, more rigorous testing will not stop the water from becoming infected; the inspection process will merely alert officials if water does become contaminated. As long as the climate continues to change, our drinking water will be at risk of becoming infected.

Waterborne parasites may be spread far and wide when the micro-organisms get carried by flood waters.

Your Turn

1. What do communities need to do to prevent the spread of waterborne diseases due to increased precipitation and higher temperatures?
2. Consider the questions you would need answered if you were developing a public health strategy to prevent waterborne diseases. Create a list outlining the most important information that you would need.
3. Choose and research one of the following common waterborne diseases: cryptosporidiosis, *E. coli* infection, giardiasis, or cholera. Write a public service announcement (PSA) to inform the public about how climate change is affecting the nature and range of this disease.

Figure 7.25 Water shortage is a problem for many farmers. In 1988, drought caused Canada's total grain production to drop by nearly one third.

Desertification, Droughts, and Other Outcomes

An increase or decrease in precipitation affects the levels of reservoirs and ground water used for drinking water. Declines in precipitation can lead to **desertification**—the spread of deserts that have a reduced capacity to support life. Desertification may lead to famines as once-farmable land becomes unable to support crops. As average temperatures rise, crop losses from drought will increase, as shown in **Figure 7.25**.

According to some sources, about half of the nations in the world may experience water shortages by 2025. By 2050, nearly 75 percent of the world's population may be affected by the scarcity of fresh water. These shortages will affect not only countries in the dry, desert regions of the world, such as northern Africa and the Middle East, but also large parts of North America. However, experts think that new technologies and policy changes may help reduce the impact of these shortages. In addition, many water conservation efforts are in place to help conserve this important natural resource.

desertification the process by which land slowly dries out until little or no vegetation can survive and the land becomes a desert

Sense of scale

Between April 1998 and May 1999, a fall in the levels of the Great Lakes resulted in the loss of about 120 km^3 of water from the system. That volume of water takes almost two years to flow over Niagara Falls.

Storm Intensity and Frequency

In August 2005, an intense storm system moved across southwestern Ontario. Up to 153 mm of rain fell during a period of about four hours. By the time the storm had passed, it had caused more than $400 million in damage, including the damage shown in **Figure 7.26**. Every year, flooding, heavy rains, and strong winds cause extensive damage to buildings, bridges, and roads. Storms also disrupt electrical service and put people in physical danger.

Extreme storms remind people in a dramatic way of how climate affects our lives. Hurricanes are the most violent storms on Earth. They form over the tropical oceans during late summer and early fall when surface waters store the greatest amount of heat. The temperatures of the tropical waters where these tropical storms begin have increased by about 0.33°C since 1981. Over the same period, a statistically significant increase in the maximum wind speeds of the strongest hurricanes has occurred. In other words, the strongest storms have become stronger. These data are consistent with the hypothesis that warmer seas hold more energy to convert to hurricane-speed winds.

Figure 7.26 When this street collapsed in Toronto in 2005, it damaged two high-pressure gas pipes, a drinking-water pipe, and telephone, hydro, and cable service lines that were buried beneath the road.

Learning Check

1. How have changes in winds affected the amount of polar ice?
2. How might desertification affect food supplies for humans?
3. Based on the information in **Figure 7.24**, how have precipitation rates changed in Ontario since 1948?
4. Create a flowchart that shows how rising global temperature affects the likelihood that Canadians may contract waterborne diseases.

Changing Biomes

As climate conditions change, the plants and animals that are adapted to a particular region may no longer be able to survive there. An international team of researchers recently studied the likely effects of climate change on biodiversity in six different regions around the world. The data showed that 15 to 35 percent of the 1103 species in the study were at risk of extinction by 2050. The scientists then extrapolated these results to the entire planet, including ocean ecosystems. The scientists concluded that more than one million species are threatened with extinction worldwide as a result of climate change. **Figure 7.27** summarizes some of the global impacts of climate change that you have read about in this section.

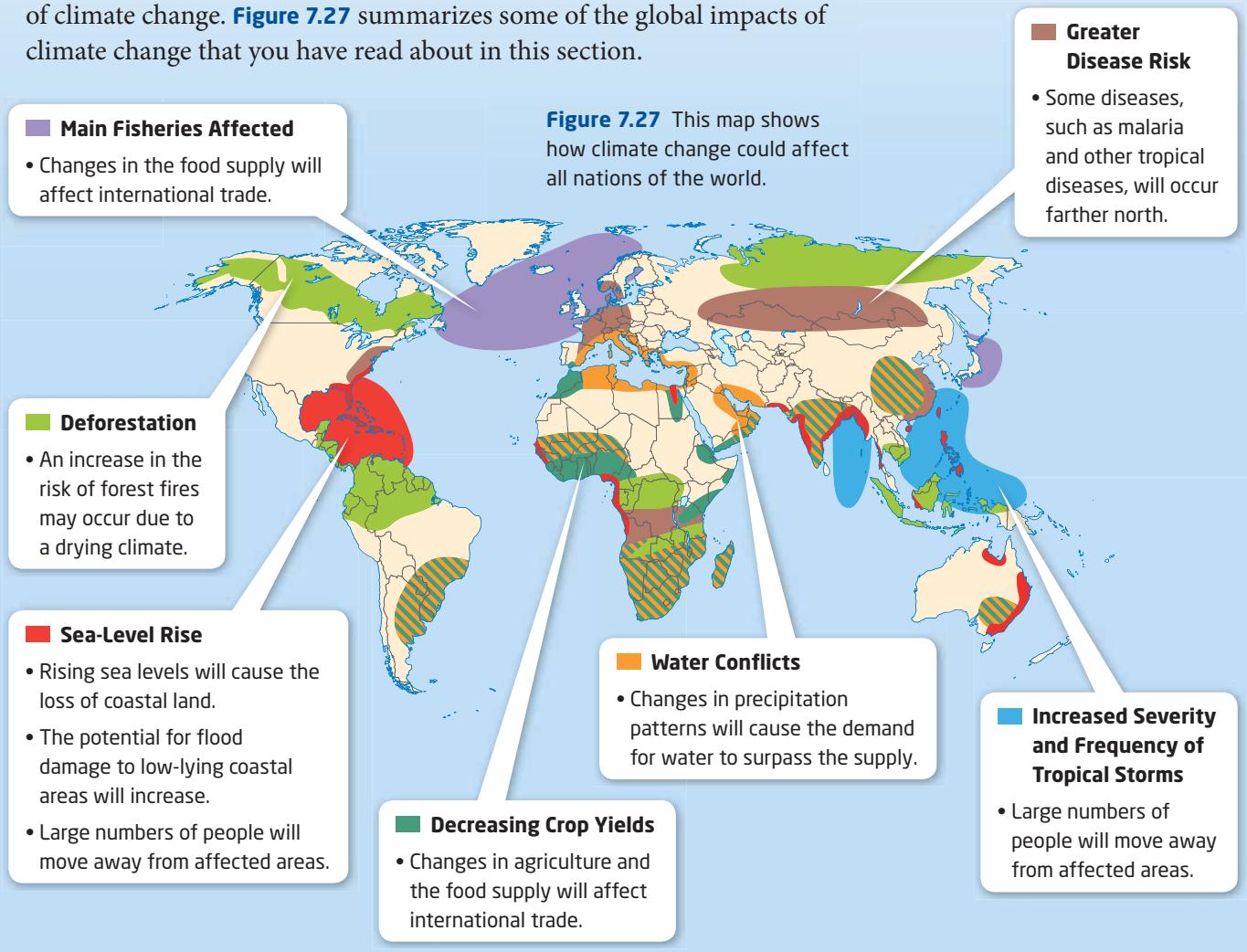

Figure 7.27 This map shows how climate change could affect all nations of the world.

Figure 7.28 The brown trees in this photo were damaged by mountain pine beetles. The spread of this beetle has been directly linked to the warming climate.

deforestation the destruction of the world's forests through direct human activity, such as logging or slash-and-burn clearing for agriculture and grazing, and through the indirect effects of climate change, pollution, and acid rain

Deforestation

The removal of trees and forests from an area is known as **deforestation**. A shrinking forest area reduces the amount of carbon dioxide (CO_2) absorbed from the atmosphere by photosynthesis. Thus, loss of trees affects climate by increasing the amount of carbon dioxide in the air.

Deforestation may occur as a result of natural phenomena or human activities. For example, global warming may lead to hot, dry summers that provide ideal conditions for forest fires. In western Canada, infestations of mountain pine beetle have killed huge areas of forest, as shown in **Figure 7.28**. In parts of eastern Canada, forests have been damaged by air pollution and acid precipitation. In addition, humans may actively clear land of forests in order to use the wood or the land.

Canada's local, provincial, and national governments have implemented many programs to protect forests and to promote reforestation. For example, in 2006, the First Nations Forestry Council received $8.4 million to respond to the damage caused by mountain pine beetles. In addition to local and national programs, many private companies provide reforestation services.

Shrinking Wetlands–and Efforts to Save Them

Besides supplying water for human needs, freshwater ecosystems play an important role in regulating climate. Wetlands, such as the one shown in **Figure 7.29**, include marshes, bogs, fens, and swamps. These ecosystems store and filter water. They are also habitats for plants that remove carbon dioxide from the air, and for a variety of animals.

Lower water levels in the Great Lakes will dry out wetlands around the shoreline, reducing habitat for wetland species of plants and animals. Conservation of Great Lakes wetland habitats has required co-operation between the Canadian and United States governments. Some of the conservation initiatives for this region include the Great Lakes Wetlands Conservation Action Plan, the North American Waterfowl Management Plan, and the formation of National Wildlife Areas and Migratory Bird Sanctuaries.

Figure 7.29 The Beverly Swamp, in southern Ontario, is a wetland habitat that is home to rare northern flying squirrels and grass-pink orchids. Conservation groups are making progress in protecting wetlands such as this one.

Section 7.3 Review

Section Summary

- Global warming is the increase in the average temperature of the atmosphere and oceans over the past 100 years. It is the largest single indicator of recent climate change.
- As global temperature rises, polar icecaps are melting, which affects the lives of Arctic mammals, such as polar bears, and of traditional Inuit peoples of Canada.
- As atmospheric and ocean temperatures increase, sea level is rising. Rising sea level will affect large populations of humans who live on islands and along the coasts of the world's continents.
- As the global oceans absorb more carbon dioxide, the water becomes more acidic, which threatens coral reefs and oceanic food chains.
- Changes in wind and precipitation result from global warming. These changes may lead to water shortages throughout the world and possibly to more frequent and stronger storms.
- Climate change may affect the health of humans by increasing the incidence of certain diseases.
- Deforestation and desertification may result from higher temperatures and changes in precipitation.

Review Questions

K/U **1.** What is the most important indicator of global climate change in recent years?

K/U **2.** How does global warming affect sea level?

K/U **3.** How might a warming climate affect human health?

C **4.** The graph below shows the number of people who visited doctors for skin disorders between January 1967 and January 1971. Write a paragraph that summarizes the relationship between temperature, humidity, and the number of skin diseases reported during that timeframe.

K/U **5.** Explain how an increase in average temperature might lead to an increase in precipitation in a region.

A **6.** Why is a changing climate more of a threat to forests than to agricultural crops?

T/I **7.** Is it reasonable to conclude that because the 2005 hurricane season produced a record number of storms and some of the strongest storms in history, global warming is causing an increase in the number and intensity of hurricanes? Explain your answer.

K/U **8.** How does climate change affect the biodiversity of a region?