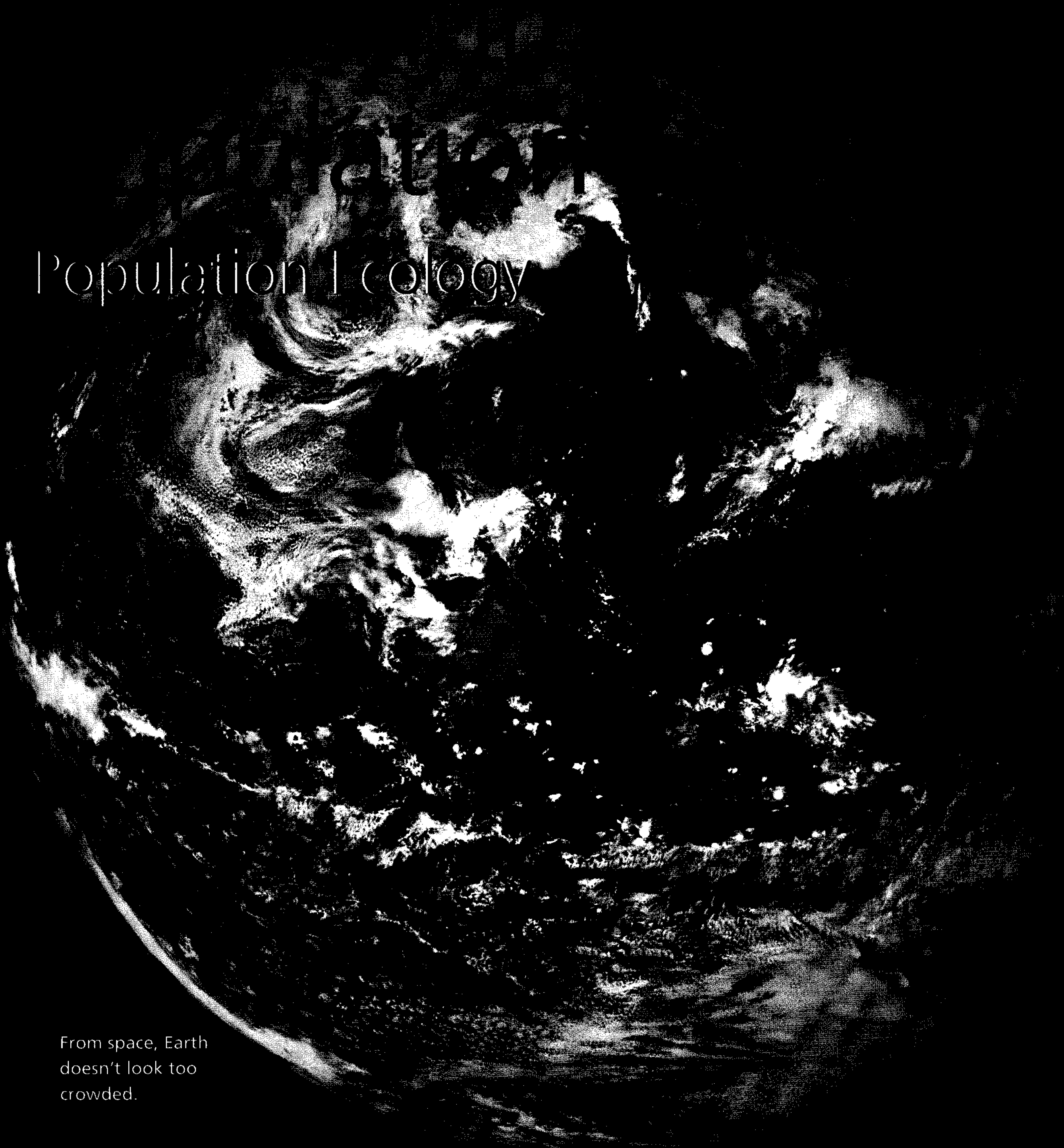
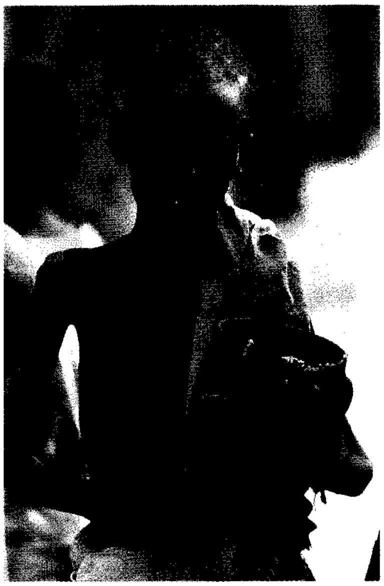
CHAPTER

Population Ecology



From space, Earth doesn't look too crowded.

But Earth's human population is 6.5 billion . . . and rising.



Is this Ethiopian child hungry because the planet is overpopulated?

Or can Earth support everyone at the same level as that of the average North American family?

In its most recent estimate in 2005, the United Nations (UN) reported that the human population on Earth is approximately 6.5 billion—double the number of people alive in 1960. The UN also predicted that the population would continue to grow for several more decades before stabilizing at as high as 10.6 billion by about 2050. As is usually the case, many observers greeted the report as another piece of bad news. While the UN's population projection is lower than past predictions (previous reports forecast a population of over 12 billion by 2050), many scientists and environmentalists wonder if our planet can support the current population for very long, let alone an additional 4.1 billion people.

Other commentators, such as the late economist Julian Simon, a former senior fellow at the influential Cato Institute, are skeptical of environmentalists' statements about population growth. They point to predictions made in the best-selling book *The Population Bomb* (1968), in which author Paul Ehrlich forecast worldwide food and water shortages by the year 2000. In fact, most measures of human health have become more upbeat since 1970, including global declines in infant mortality rates, increases in life expectancy, and a 20% increase in per capita income—despite a near doubling in population since the publication of Ehrlich's book. By most measures, the average person is better off today than in 1970. Paul Ehrlich was clearly wrong in 1968; why should we believe his doom-and-gloom predictions about the future now?

Ehrlich and his colleagues counter that while they were wrong about how soon it would happen, there are some indications that the large human population is rapidly reaching a real limit to growth. For example, the UN previously released another report—*The State of Food and Agriculture, 2003–2004*—describing numerous food crises around the world. According to the UN, as of August 2003, thirty-eight countries and over 62 million people were facing food emergencies, meaning that starvation could be imminent. Worldwide, 842 million people—including 150 million children under the age of 5—do not get enough food regularly for a healthy existence. A staggering 55% of the nearly 12 million deaths each year among children under 5 in the developing world are associated with inadequate nutrition. Despite years of international attention and billions of dollars spent to address this problem, the situation has not improved dramatically—there are only 10% fewer children suffering from malnutrition today than there were in 1980.

So what is the truth? Is the human population larger than Earth can support for much longer? Are we headed into a global food crisis and massive famine? Or are we gradually moving toward an era where all people on Earth will be as well-fed, long-lived, and affluent as the average North American?

13.1 A Growing Human Population

Ecology is the field of biology that focuses on the interactions among organisms as well as between them and their environment. The relationship between organisms and their environments can be studied at many levels—from the individual, to populations of the same species, to communities of interacting species, and finally to the effects of biological activities on the nonbiological environment, such as the atmosphere. The three chapters in this unit present basic ecological principles obtained from the study of ecology at all of these levels.

From an ecological perspective, a **population** is defined as all of the individuals of a species within a given area. Populations exhibit a structure, which includes the spacing of individuals (that is, their distribution) and their density (abundance). Much of the science of ecology is concerned with the factors influencing the distribution and abundance of the individuals within populations. The interactions among species described in Chapter 14 make up one set of influences, but another set is the dynamics of the population, including the relative numbers of individuals of different sexes and ages and the numbers that are born or die in a given time period.

Population Structure

The first task of a population ecologist is to understand how many individuals make up the population of interest. Certain populations can be counted directly, as in a census tabulating the number of humans in an area or a survey identifying all individuals of a particular tree species in a forest tract. The size of more mobile and inconspicuous species can be estimated by the **mark-recapture method**. In this technique, researchers capture many individuals, mark them in some way (for instance, with an ear tag) and release them back into the environment. At some later time, the researchers capture another group of individuals and calculate the proportion of previously marked individuals in this group. This proportion can be used to estimate the size of the total population. For example, imagine that a researcher captured, marked, and released 100 beetles. If he returns a week later and finds that 10% of the beetles he caught on the second round are marked,

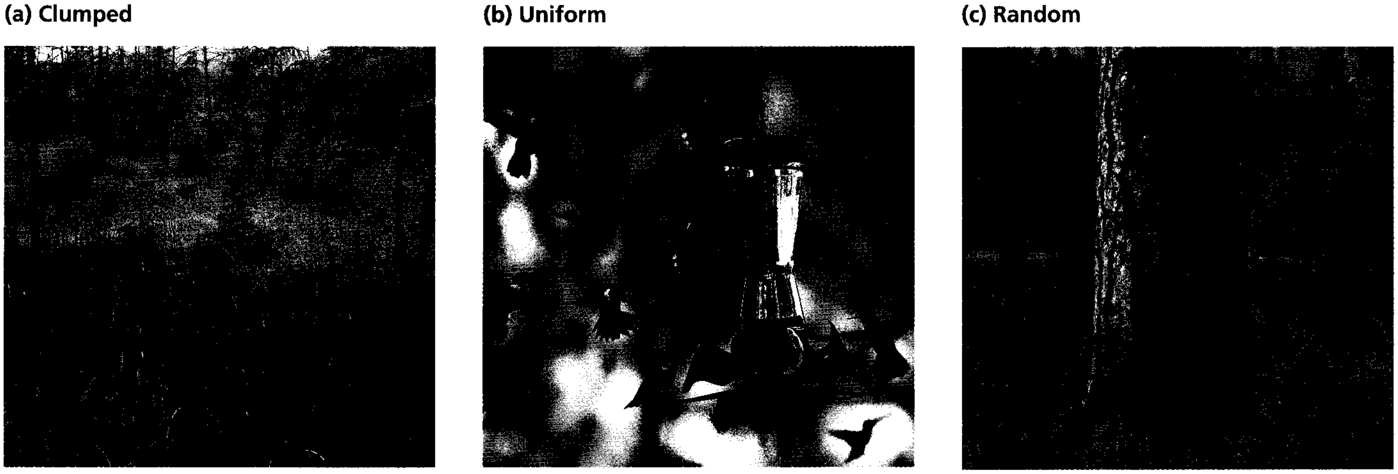


Figure 13.1 Patterns of population dispersion. Individuals in a population may be (a) clumped, like these cattails growing in soil with the correct water content; (b) uniformly distributed, like these birds at a feeder; or (c) randomly dispersed, like these seedlings in a forest.

he can assume that the 100 beetles he marked originally represented 10% of the entire beetle population. According to this mark-recapture survey, the total population is approximately 1000 beetles.

Another basic aspect of population structure is dispersion—that is, how organisms are distributed in space. Many species show a **clumped distribution**, with high densities of individuals in certain resource-rich areas and low densities elsewhere. Plants that require certain soil conditions and the animals that depend on these plants tend to be clumped (Figure 13.1a). On a global scale, humans show a clumped distribution, with high densities found around transportation resources such as rivers and coastlines. This clumped distribution masks a more **uniform distribution** on a local scale; for instance, the spacing between houses in a subdivision or strangers in a classroom tends to equalize the distances among individual property owners or people. Species that show a uniform distribution are often territorial—they defend their own personal space from intruders. Human territoriality has a social component; for instance, you may have noticed the variation among cultures, even within the same country, regarding how much space between two conversing people is appropriate. However, spacing between humans has a biological component, just as in other species—we all react strongly, and physically, to invasions of our socially delineated personal space. We can observe these same strong reactions among certain species of birds at bird feeders (Figure 13.1b). Nonsocial species with the ability to tolerate a wide range of conditions typically show a **random distribution**, wherein no compelling factor is actively bringing individuals together or pushing them apart. The distribution of seedlings of trees with windblown seeds is often random (Figure 13.1c).

A population's distribution and abundance provides a partial snapshot of its current situation. The dispersion of the human population—and recent changes in that pattern—profoundly affects the natural environment, as discussed in Chapter 15. However, to better understand how a population is responding to its environment, we need to determine how it is changing through time.

Population Growth

Historians have been able to use archaeological evidence and written records to determine the size of the human population on Earth at various times during the past 10,000 years. This record, presented in Figure 13.2, dramatically illustrates the pattern of population growth. For most of our history, the human population has remained at very low levels. At the beginning of the agricultural era, about 10,000 years ago, there were approximately 5 million humans. There were 100 million people during the Egyptian Empire (7000 years later) and about 250 million at the dawn of the Christian religion in 1 C.E. (C.E. refers to Common Era, the year designation used by most Western countries). The population was growing, but at a very slow rate—approximately 0.1% per year. Beginning around 1750, the rate at which the human population was growing jumped to about 2% per year. The human population reached 1 billion in 1800, had doubled to 2 billion by 1930, and then doubled again to 4 billion by 1970. Although the current growth rate is slower, about 1.2% per year, the rapid increase in population looks quite dramatic on a graph of human population over time.

The graph of human population growth is a striking illustration of **exponential growth**—growth that occurs in proportion to the current total. In other words, populations growing exponentially do not add a fixed number of offspring every year; instead, the quantity of new offspring is an ever-growing number. Exponential growth results in the J-shaped growth curve seen in Figure 13.2. The larger a population is, the more rapidly it grows because an increase in numbers depends on individuals reproducing in the population. So, while a growth rate of 1.2% per year may seem rather small, the number of individuals added to the 6.5-billion-strong human population every year at this rate of growth is a mind-boggling 77 million (approximately the entire population of Germany). Put another way, three people are added to the world population per second, and about a quarter of a million people are added every day.

What has fueled this enormous increase in human population? The annual **growth rate** of a population is the percent change in population size over a single year. Growth rate is a function of the birth rate of the population (the number of births averaged over the population as a whole) minus the death rate (the number of deaths averaged over the population as a whole). For example, 22 babies are born per year, on average, in a group of 1000 people—that is, the birth rate for the population is 2.2%:

$$\frac{22}{1000} = 0.022 = 2.2\%$$

In addition, each year 10 individuals die out of every 1000 people, resulting in a death rate of 1.0%:

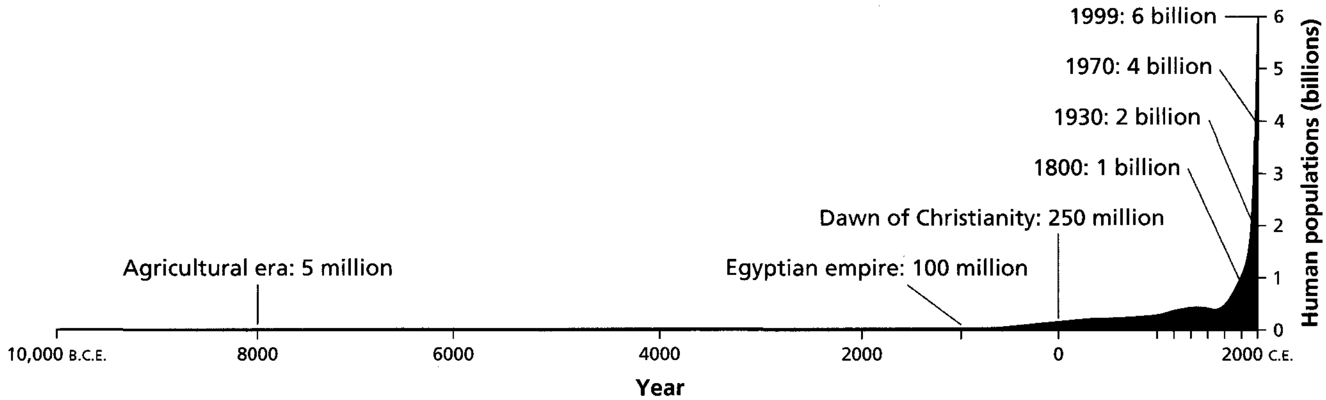


Figure 13.2 Human population growth. Estimates of human populations indicate that the number of people on Earth grew relatively slowly from the origin of agriculture through the eighteenth century. Beginning around the time of the Industrial Revolution, growth rates and population numbers began to soar.

$$\frac{10}{1000} = 0.01 = 1\%$$

This results in the current growth rate of 1.2%:

$$\text{growth rate} = \text{birth rate} - \text{death rate}$$
$$1.2\% = 2.2\% - 1.0\%$$

Today's relatively high growth rate, compared to the historical average of 0.1%, is the result of a large difference between birth rates and death rates.

In human populations, the tendency has been for decreases in death rate to be followed by decreases in birth rate. The speed of this adjustment helps to determine population growth in the future.

The Demographic Transition

Prior to the Industrial Revolution, both birth rates and death rates were high in most human populations. Although women gave birth to many children, relatively few children lived to reach adulthood. The rapid increase in population growth rate that occurred in the eighteenth century resulted from a dramatic decrease in infant mortality (the death rate of infants and children) in industrializing countries. In particular, new knowledge of how deadly infectious diseases could be prevented greatly reduced the number of children who suffered from these illnesses. With birth rates high and death rates declining, the population growth rate increased. Not long after death rates declined in these countries, birth rates followed suit, lowering growth rates again. Scientists who study human population growth refer to the period when birth rates are dropping toward lowered death rates as the **demographic transition** (Figure 13.3). The length of time that a human population remains in the transition has an enormous effect on the size of that population. Countries that pass through the transition swiftly remain small, while those that take longer can become extremely large. Countries that began the process of industrialization in the eighteenth century and that now have a high per capita income are called more developed countries. These include countries in Western Europe, North America, and Japan. Nearly all more developed countries have already passed through the demographic transition and have low population growth rates.

However, global human population growth rates have remained high because the least developed countries (countries that are early in the process of industrial development and have low per capita incomes) remain in the

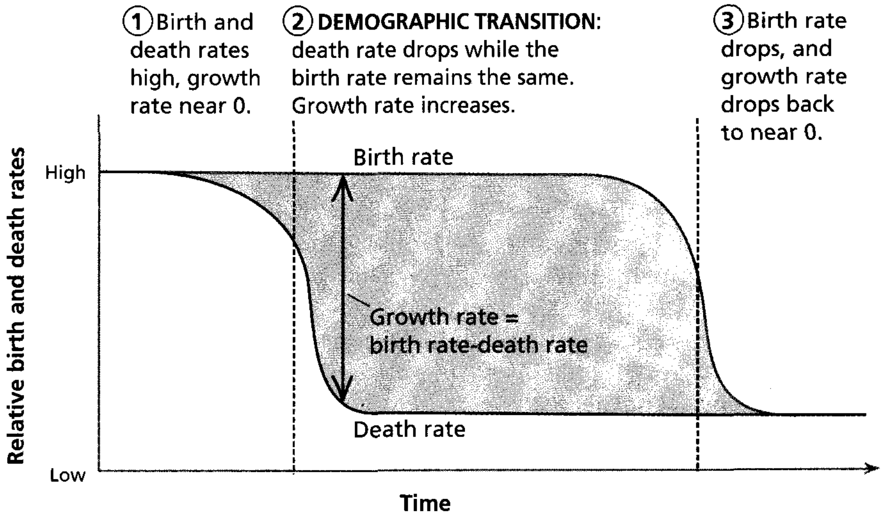


Figure 13.3 The demographic transition. As improvements in sanitation and medical care in human populations cause a decrease in infant mortality, death rates drop and growth rates soar. Eventually, people in these populations respond by decreasing the number of children they have. The longer a country remains in the transitional period, the larger its population becomes.

demographic transition. In addition, several recent changes have decreased infant mortality even more dramatically. These changes include the use of pesticides to reduce rates of mosquito-borne malaria, immunization programs against cholera, diphtheria, and other fatal diseases, and the widespread availability of antibiotics. While birth rates are gradually declining in less developed countries, they still remain high, contributing to high growth rates. The vast majority of future population growth will occur within populations in the less developed world, especially those in Africa and Asia, but these countries are where the vast majority of food crises are occurring. Are the populations in these countries already too large to support themselves? Answering that question requires an understanding of the factors that limit population growth.

13.2 Limits to Population Growth

In their study of nonhuman species, ecologists see clear limits to the size of populations. They can also observe the sometimes awful fates of individuals in populations that outgrow these limits. For this reason, many professional ecologists express grave concern about the consequences of a rapidly growing human population.

You may know of several instances of nonhuman populations outgrowing their food supplies. The elk population in Yellowstone National Park suffered enormous mortality throughout the 1970s after it grew so large that it degraded its own rangeland. The massive migrations of Norway lemmings that occur every 5 to 7 years and lead to many deaths result from population crowding; while these animals do not commit "mass suicide," as often assumed, the loss of high-quality food in an area as populations increase incite the lemmings to disperse and often meet their death in the process. Even yeast in brewing beer grow large populations that eventually use up their food source and die off during the fermenting process. Let us explore what ecology can tell us about the likelihood of human populations suffering the same fate as elk, lemmings, or yeast.

Carrying Capacity and Logistic Growth

The examples of the elk in Yellowstone and the Norway lemmings illustrate a basic biological principle. While populations have the capacity to grow exponentially, their growth is limited by the resources—food, water, shelter, and space—that individuals need to survive and reproduce. The maximum population that can be supported indefinitely in a given environment is known as the environment's **carrying capacity**.

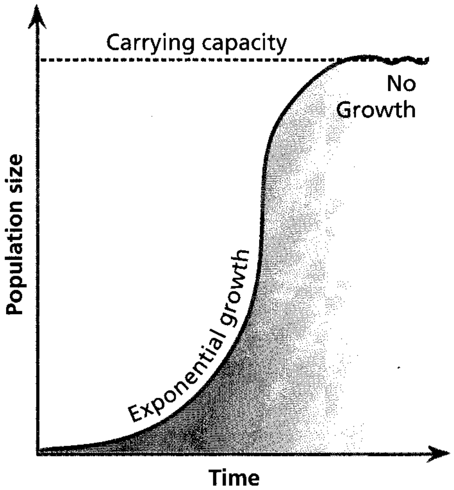
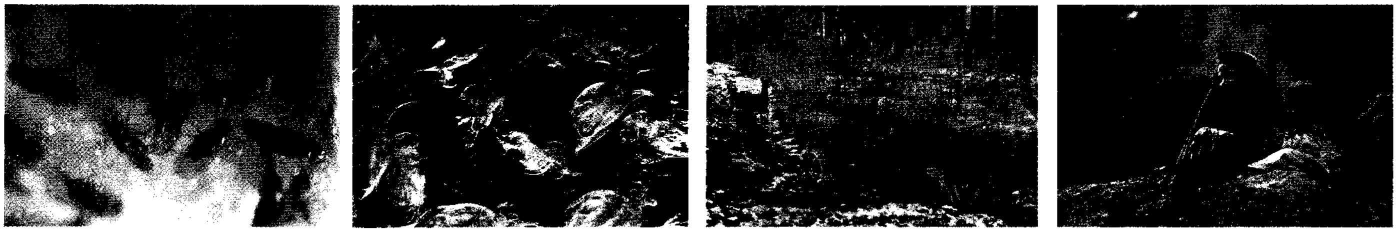


Figure 13.4 The logistic growth curve. This graph illustrates the change in size of an idealized population over time. The S-shaped curve is due to a gradual slowing of the population growth rate as it approaches the carrying capacity of the environment.

The growth of a population in an environment where resources are limited is exponential at first, but the effects of declining resources gradually take their toll on growth rate. A simplified graph of population size over time in resource-limited populations is S-shaped (Figure 13.4). This model shows the growth rate of a population declining to zero as it approaches the carrying capacity. In other words, birth rate and death rate become equal, and the population stabilizes at its maximum size. Not long after ecologists first predicted this pattern of growth, called logistic growth, populations of organisms as diverse as flour beetles, water fleas, and single-celled protists were shown in laboratory studies to conform with this projected growth curve.

The declining growth rate near a population's carrying capacity is caused by **density-dependent factors**, which are population-limiting factors that increase in intensity as the population increases in size. Density-dependent factors include limited food supplies, increased risk of infectious disease in more crowded conditions, and an increase in toxin concentration caused by in-



(a) Fruit flies

(b) Water fleas

(c) White-tailed deer

(d) Humans

Figure 13.5 Limits to growth. Populations of (a) fruit flies in a laboratory culture, (b) water fleas in an aquarium, and (c) white-tailed deer in the northeastern United States all experience high death rates and/or low birth rates as their populations approach the carrying capacity of the environment. (d) Do human populations face these same limits?

creased waste levels. Density-dependent factors cause declines in birth rate or increases in death rate. In organisms such as fruit flies growing in laboratory culture bottles, high populations lead to increased mortality of the flies as food supplies dwindle and wastes accumulate. Water fleas living in crowded aquariums do not have enough food to support egg production, and so birth rates drop. Females of white-tailed deer populations living in crowded natural habitats are less likely to be able to carry a pregnancy to term than deer in less-crowded environments. Density-dependent factors can be contrasted with **density-independent factors** that influence population growth rates—for instance, severe droughts that increase the death rate in plant populations regardless of their density, or increased temperatures that increase the birth rate in cold-limited insects. However, density-independent factors do not occur in a vacuum; they can have more or less severe effects depending on the size of a population. For example, a density-independent factor such as an unusually cold winter can be deadly to individuals in a white-footed mouse population, but the likelihood of survival is also a function of how much food each individual has stored for the winter. How much food is stored depends on the density of mice competing for food sources during the autumn.

Are density-dependent factors beginning to reduce growth rates in a human population? That is, are humans nearing the carrying capacity of Earth for our population? If we are, will death rates increase as food resources dwindle and more people starve? Or will birth rates decline because fewer women will have enough food to support themselves *and* a developing baby (Figure 13.5)?

Earth's Carrying Capacity for Humans

One way to determine if the human population is reaching Earth's carrying capacity is to examine whether, and how rapidly, the growth rate is declining. As we saw in Figure 13.4 on page 350 the S-shaped curve of population size over time results from a gradually declining growth rate as the population approaches carrying capacity.

Human population growth rates were at their highest in the early 1960s, about 2.1% per year, but they have since declined to the current rate of 1.2%. This steady decline is one indication that the population, though still currently growing, is nearing a stable number. Uncertainty about the future rate of growth has led the UN to produce differing estimates of this number and how soon population stability will be reached (Figure 13.6). However, the unique characteristics of humanity make it difficult to determine exactly which population size represents Earth's carrying capacity for humans.

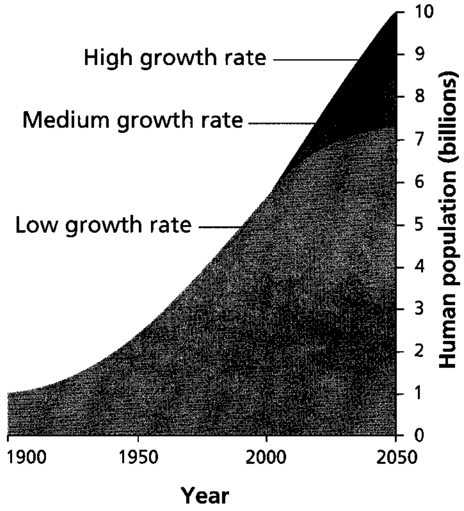


Figure 13.6 Projected human population growth. The United Nations' report predicting the eventual size of the human population is based on a number of uncertainties and leads to three projections: a low-growth scenario of 7.2 billion people; medium growth resulting in 8.6 billion; or even a high-growth estimate of 10.3 billion.

Signs That the Population Is Not Near Carrying Capacity. The rates of population increase of fruit flies and water fleas in the laboratory have slowed as these populations neared carrying capacity because their growth rates were forced down by density-dependent factors; lack of resources caused increased death rates or decreased birth rates. However, this is not the case in human populations. Even as the human population has rapidly increased, death rates continue to decline—an indication that people are not limited by food resources. Growth rates are declining because birth rates are falling faster than death rates. Unlike the water fleas and white-tailed deer, whose females are unable to have offspring when populations are near carrying capacity, birth rates in human populations are falling because women and families, even those with adequate resources, are *choosing* to have fewer children.

Although the human population's growth rate is slowing as might be expected near carrying capacity, rising living standards indicate that the population is not currently experiencing a density-dependent factor. Another way to determine if we are near Earth's carrying capacity is to estimate the amount of resources that are currently being used by humans and use that estimate to approximate the theoretical limit to population size. The amount of food energy available on the planet is referred to as the **net primary production (NPP)**. NPP is the amount of solar energy captured via plant photosynthesis minus the amount of energy that plants need to support themselves. In other words, NPP is a measure of plant growth, typically over the course of a single year. Several different analyses of the global extent of agriculture, forestry, and animal grazing estimate that humans use roughly one-third of the total land NPP. If we accept these rough estimates, we can approximate that the carrying capacity of Earth is three times the present population, or approximately 19 billion people. This theoretical maximum is the total number of humans that could be supported by all of the photosynthetic production of the planet—leaving no resources for millions of other species. Given the dependence of humans on natural systems (explored in Chapter 14), it is unlikely that our species could survive on a planet where no natural systems remained. However, even the largest population projection by the UN, 10.6 billion, falls well short of this theoretical maximum.

Signs That the Population Is Near Carrying Capacity. Ecologists caution that the resources required to sustain a population include more than simply food, and so the carrying capacity deduced from NPP estimates may be much too high. Humans also need a supply of clean water, clean air, and energy for essential tasks such as heating, food production, and food preservation. The relationship between population size and the supply of these resources is not as straightforward as the relationship between population and food. For instance, every new person added to the population requires an equivalent amount of clean water, but every new person also introduces a certain amount of pollution to the water supply. We cannot simply divide the current supply of clean water by 10.6 billion to determine if enough will be available in the future, since increased population leads to increased pollution and therefore less total clean water.

Furthermore, many essential supplies that sustain the current human population are **nonrenewable resources**, meaning that they are a one-time stock and cannot be easily replaced. The most prominent nonrenewable resource is fossil fuel, the buried remains of ancient plants transformed by heat and pressure into coal, oil, and natural gas. The use of fossil fuel and other nonrenewable resources is a function not only of the number of people but also of average lifestyles, which vary widely around the globe. For example, Americans make up only 5% of Earth's population but are responsible for 24% of global energy consumption. The average American uses as many resources as 2 Japanese or Spaniards, 3 Italians, 6 Mexicans, 13 Chinese, 31 Indians, 128 Bangladeshis, 307 Tanzanians, or 370 Ethiopians. Americans also consume a total of 815 billion food calories per day—about 200 billion calories more than is required, or enough to feed an additional 80 million people. Much of modern food production relies on the energy provided by fossil fuel. When these resources begin to run out, we might find that we need far more of Earth's NPP than we do now to sustain abundant food production. In other words, the actual carrying capacity of our planet may be much lower than our approximations.

The question posed at the beginning of this section remains unanswered; there is no agreement among scientists concerning the carrying capacity of Earth for the human population. Given that uncertainty, what can ecologists tell us about the risks facing the human population that may result from massive, rapid population growth?

13.3 The Future of the Human Population

Unlike nearly all other species, human populations are not simply at the mercy of environmental conditions. With its ability to transform the natural world, human ingenuity has helped populations circumvent seemingly fixed natural limits. However, ingenuity has a dark side, in that it can lull people into believing that nature has an almost infinite capacity to support their ever-growing needs. Managing the growth of human populations before even the most secure of them face environmental and economic disaster requires an understanding of the risks of continued rapid growth and the strategies that help reduce it.

A Possible Population Crash?

The use of nonrenewable resources creates a risk of the human population overshooting a still unknown carrying capacity. Ecologists have long known that when populations have high growth rates, they may continue to add new members even as resources dwindle. This causes the population to grow larger than the carrying capacity of the environment. The members of this large population are then competing for far too few resources, and the death rate soars while the birth rate plummets. This results in a **population crash**, a steep decline in number (Figure 13.7). For instance, in some species of water flea, healthy offspring continue to be born for several days after the food supply becomes inadequate because females can use their fat stores to produce additional young. The size of the population continues to rise even when there is no food left to graze on; however, when these young water fleas run out of stored fat, most individuals die. For many species with high birth rates, rapid growth followed by dramatic crashes produce a **population cycle** of repeated "booms" and "busts" in number.

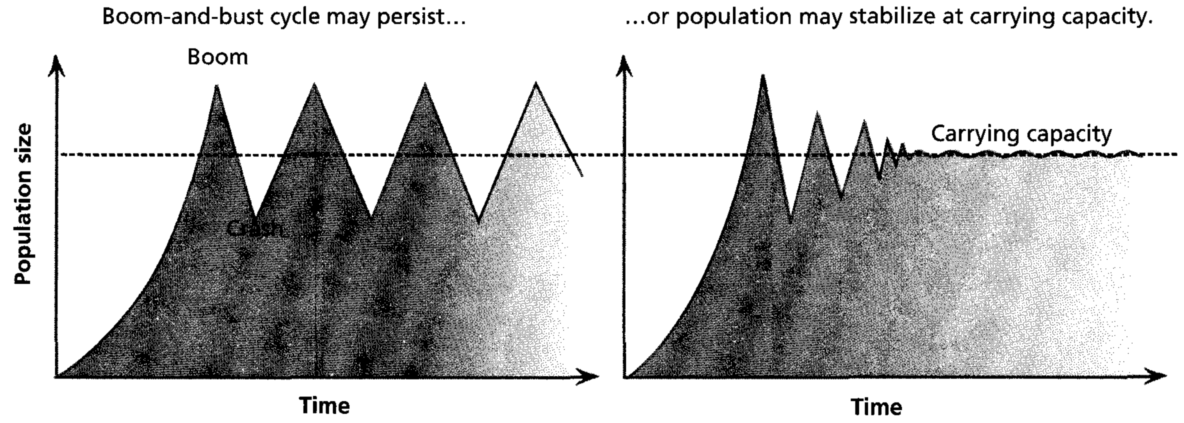
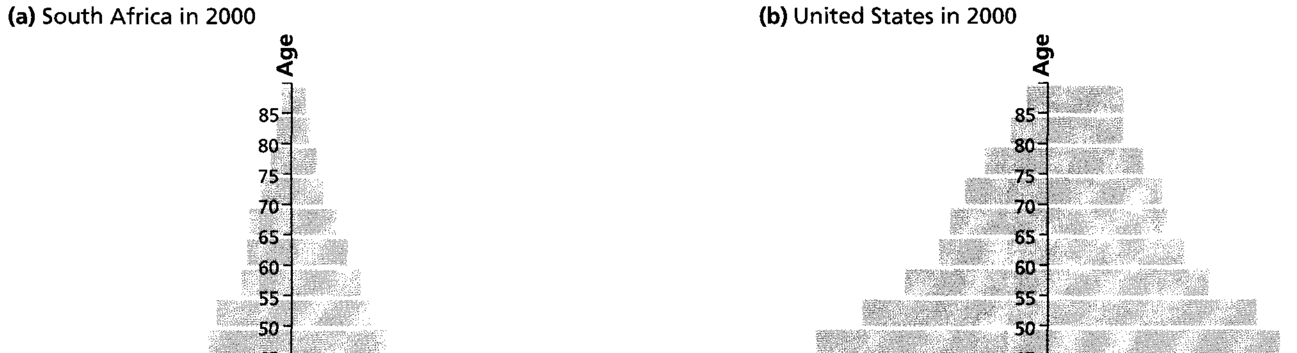


Figure 13.7 Overshooting and crashing. These graphs illustrate rapid population growth followed by a population crash. Over time, the population may stay in a "boom-and-bust" cycle, or it may stabilize at its carrying capacity.

Figure 13.8 The crash of a human population. On Rapa Nui, also known as Easter Island, the human inhabitants created these large statues. Soon after completely deforesting this small island, the large population suffered a severe crash.

A population overshoot and subsequent crash affected the human population on the Pacific island of Rapa Nui (also known as Easter Island) during the eighteenth century (Figure 13.8). This 150-square-mile island is separated from other landmasses by thousands of miles of ocean; therefore, its people were limited to using only the resources on or near their island. Archaeological evidence suggests that at one time, the human population on Rapa Nui was at least 7000—apparently a number far greater than the carrying capacity of the island. By 1775, the subsequent overuse and loss of Rapa Nui's formerly lush palm forest had resulted in a rapid decline to fewer than 700 people, a population likely much lower than the initial carrying capacity of the island. It is possible that humanity's use of the stored energy in fossil fuels may be allowing us to overshoot Earth's true carrying capacity.

Biological populations may also overshoot carrying capacity when there is a time lag between when the population approaches carrying capacity and when it actually responds to that environmental limit. Scientists who study human populations note a lag between the time that humans reduce birth rates and when population numbers respond. They call this lag **demographic momentum**. The momentum occurs because while parents may be reducing their family size, their children will begin having children before the parents die, causing the population to continue growing. Even when families have an average of two children, just enough to replace the parents, demographic momentum causes the human population to grow for another 60 to 70 years before reaching a stable level. The potential demographic momentum of a population can be estimated by looking at its **population pyramid**, a summary of the numbers and proportions of individuals of each sex and each age group. As Figure 13.9 illustrates, the potential for high levels of demographic momentum occurs when the age structure most closely resembles a true pyramid, with a large proportion of young people. In more stable populations, the proportion that is young is



(a) South Africa in 2000

(b) United States in 2000

Figure 13.9 Demographic momentum. In a rapidly growing human population like that of (a) South Africa in 2000, most of the population is young, and the population will continue to grow as these children reach child-bearing age. In a slower-growing or stable human population, the ages are more evenly distributed, as in (b) the United States in 2000.

not significantly larger than the proportion that is middle aged, and the pyramid looks more like a column.

Whether or not our reliance on stored resources and the potential demographic momentum in human populations will result in an overshoot of Earth's carrying capacity—followed by a severe crash, as on the island of Rapa Nui—remains to be seen. But human ecologists already know what factors help to slow population growth so that a crash may become less likely.

Avoiding Disaster

As discussed earlier in the chapter, when death rates drop in human population, birth rates eventually follow. Unlike any other species known to science, humans will voluntarily limit the number of babies they produce. When more opportunities become available outside of child rearing, most women delay motherhood and have fewer children. In fact, birth rates are lowest in countries where income is high and women are provided with education (Figure 13.10). This information provides a clear direction for public policies attempting to decrease population growth rates: improve conditions for women, including increasing access to education, health care, and the job market, and provide them with the information and tools that allow them to regulate their fertility.

Slowing growth rates before the human population reaches some environmentally imposed limit has additional benefits. Determining Earth's carrying capacity for humans as simply a function of whether food and water will be available also ignores quality-of-life issues, or what some scientists call cultural carrying capacity. An Earth that was wholly given over to the production of food for the human population would lack wild, undisturbed places and the presence of species that nurture our sense of wonder and discovery. With human populations at the limits of growth, much of our creative energy would be used for survival, taking away our ability to make and enjoy music, art, and literature. Limiting human population growth also leaves room for nonhuman species. As we discuss in Chapter 14, human activity is posing a direct threat to the survival of a significant percentage of Earth's biodiversity—a threat that

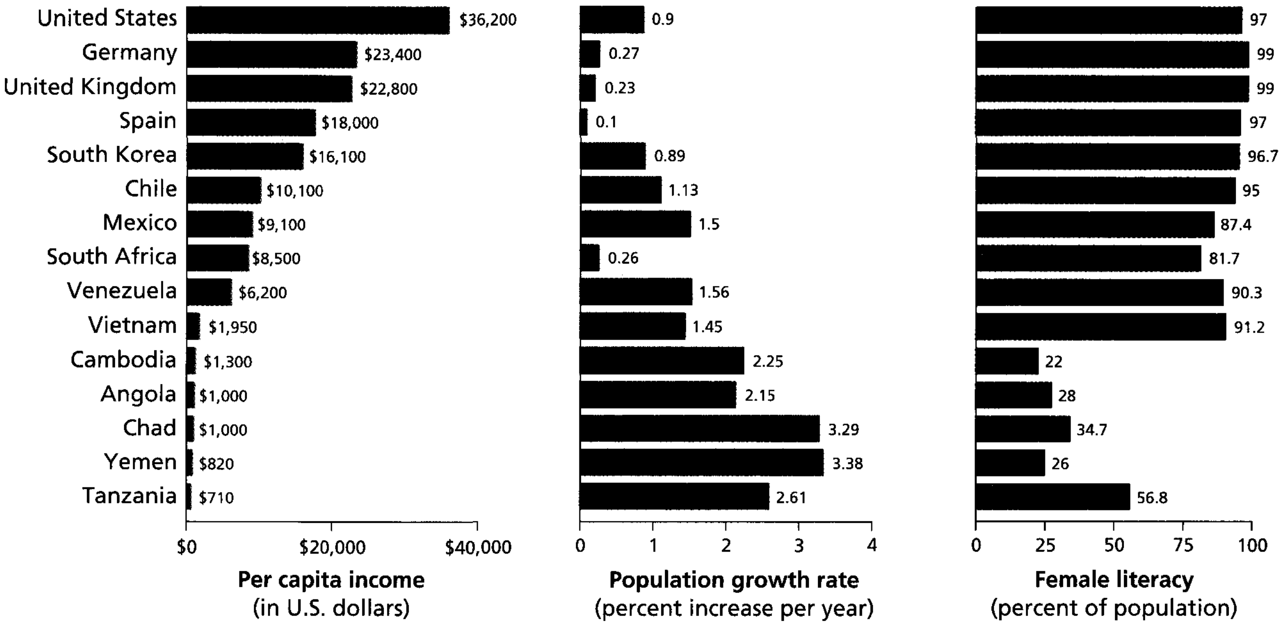


Figure 13.10 Income, growth rate, and women's literacy. These three graphs illustrate the relationships among income, population growth, and female literacy. Note that higher income and literacy are correlated with decreased birth rates and thus decreased population growth in most countries.

increases in direct proportion to the size and affluence of the planet's human population.

What we have learned is that scientists cannot tell us exactly how many people Earth can support, partly because humans make unpredictable choices and partly because humans have the capacity to innovate and adjust seemingly fixed biological limits. Ultimately, the question of how many people Earth should support—and at what quality of life, or including support for nonhuman species—is a question not solely of science but also of values and ethics.

CHAPTER REVIEW

Summary

13.1 A Growing Human Population

- A population is defined as a group of individuals of the same species living in a fixed area. The structure of a population can be described by the number of individuals and their dispersion (p. 346).
- The human population has grown very rapidly over the last 150 years and exhibits a pattern of exponential growth, which is an increase in numbers as a function of the current population size (p. 348).
- Human population growth is spurred by decreases in death rate caused by decreased infant mortality. In most populations, this decrease is followed by a decrease in birth rates. The gap between when death rates drop and birth rates follow is called the demographic transition (pp. 348–349).

Web Tutorial 13.1 Population Growth

13.2 Limits to Population Growth

- Nearly all populations eventually reach the carrying capacity of their environment. Near carrying capacity, density-dependent factors cause an increase in death rate (p. 350).
- The growth rate of the human population is declining, but not as a result of density-dependent factors. Instead, birth rates are dropping because women are choosing to have fewer children (p. 351).
- Rough calculations indicate that the energy received from the sun each year could support a population of 19 billion people, well over the largest population projections (p. 352).
- Humans' reliance on nonrenewable resources may be temporarily inflating the actual carrying capacity of Earth (pp. 352–353).

13.3 The Future of the Human Population

- Fast-growing populations that overshoot their environment's carrying capacity may experience a crash or go through periodic booms and busts (p. 353).
- It is possible that the human population will overshoot Earth's carrying capacity because of our reliance on nonrenewable resources and due to demographic momentum (p. 354).
- Human population growth rates decline when women are empowered to seek an education and may choose to work outside the home (p. 355).

Learning the Basics

1. What factors have led to the explosive increase in the human population over the past 150 years?

2. Explain why a decrease in population growth rate is expected as a nonhuman population approaches carrying capacity.

3. Describe why demographic momentum may cause the human population to overshoot Earth's carrying capacity.

4. When individuals in a population are evenly spaced throughout their habitat, their dispersion is termed as ______________.

   A. clumped; **B.** uniform; **C.** random; **D.** excessive; **E.** exponential

5. The growth of human populations over the past 150 years has increased primarily due to ______________.

   A. increases in death rate; **B.** increases in birth rate; **C.** decreases in death rate; **D.** decreases in birth rate; **E.** increases in net primary production

6. According to Figure 13.11, the carrying capacity for fruit flies in the environment of the culture bottle is ______________.

   A. 0 flies; **B.** 100 flies; **C.** 150 flies; **D.** between 100 and 150 flies; **E.** impossible to determine

7. In contrast to nonhuman populations, human population growth rates have begun to decline due to ______________.

   A. voluntarily increasing death rates; **B.** voluntarily decreasing birth rates; **C.** involuntary increases in death rates; **D.** involuntary decreases in birth rates; **E.** voluntarily increasing birth rates

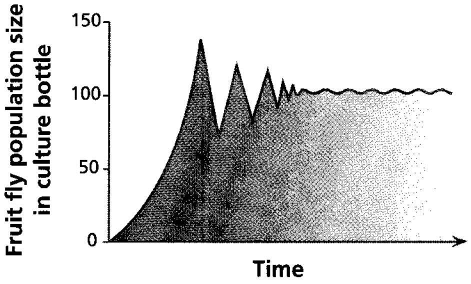


Figure 13.11

8. Populations that rely on stored resources are likely to overshoot the carrying capacity of the environment and consequently experience a ______________.

   A. demographic momentum; **B.** cultural carrying capacity; **C.** decrease in death rates; **D.** population crash; **E.** exponential growth

9. Demographic momentum refers to the tendency for ______________.

   A. low population growth rates to continue to decline; **B.** high population growth rates to continue to increase; **C.** populations to continue to grow in number even when growth rates reach zero; **D.** populations to continue to grow in number even when women are reducing the number of children they bear; **E.** women to continue to have children even though they no longer wish to

10. Which of the following factors is associated with declines in a country's population growth rate?

    A. an increase in per capita income; **B.** an increase in female educational attainment; **C.** an increase in women's social status; **D.** a and c are correct; **E.** a, b, and c are correct

Analyzing and Applying the Basics

1. A researcher captures 50 penguins, marks them with a spot of paint on their bills, and releases them. One month later she returns, captures another 50 penguins, and notes that only 1 has a previous mark. What is the likely size of the total penguin population in the researcher's study area?

2. Review Figure 13.11 above. How would you expect the carrying capacity of the population to change if the flies are supplied with a greater amount of food? What other factors might influence the carrying capacity in this environment?

3. Imagine two human populations, each one made up of 5 million individuals. In one population, over 50% of the members are in the age group of 0 to 20 years and about 2% are over 65. In the other population, about 20% are from 0 to 20 years old and about 20% are over 65. Which of these populations will probably stabilize at a larger number, and why?

Connecting the Science

1. Review your answer to Question 2 in "Analyzing and Applying the Basics." How are the factors that limit fruit-fly populations in a culture bottle similar to the factors that limit human populations on Earth? How are they different?

2. Africa is the only continent where increases in food production have not outpaced human population growth. Many of the most severe food crises are in African countries. Should those of us in the more developed world assist African populations? How? What factors influence your thoughts on this question?