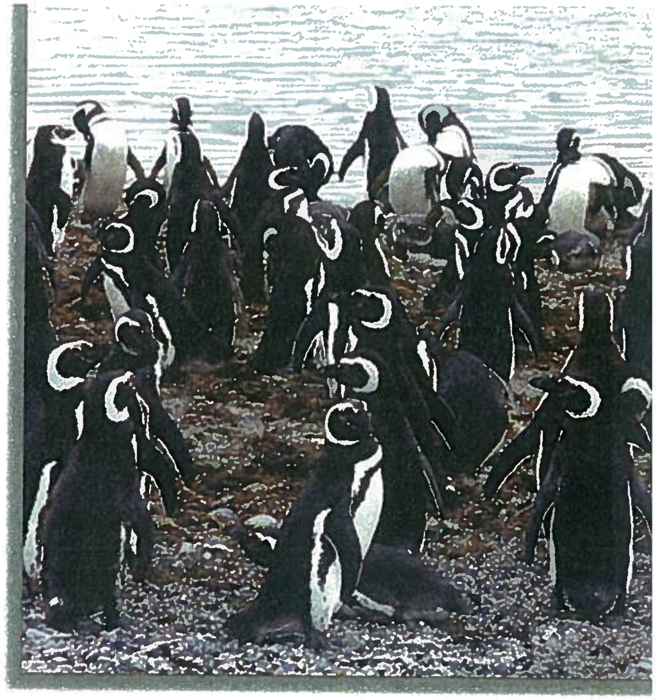
CHAPTER 7

POPULATIONS: CHARACTERISTICS AND ISSUES



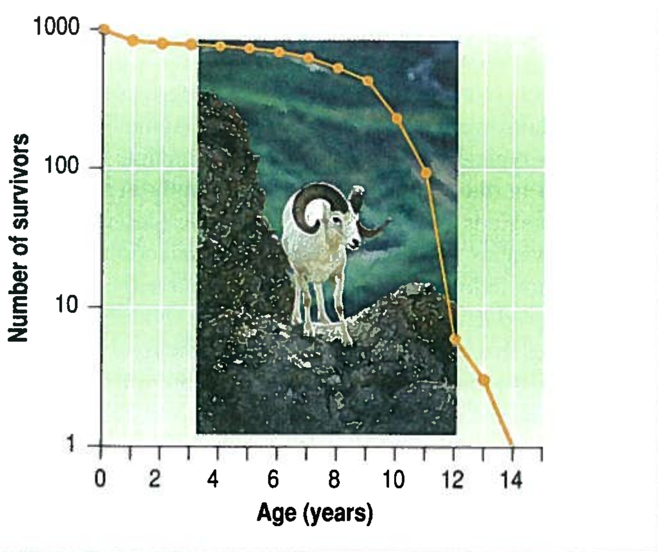
Populations are collections of organisms of the same species. This group of Magellanic penguins constitutes a population with certain characteristics that may differ somewhat from the characteristics of penguin groups that inhabit other parts of South America.

CHAPTER OUTLINE

OBJECTIVES

After reading this chapter, you should be able to:

- Understand that birthrate and death rate are both important in determining the population growth rate.
- Define the following characteristics of a population: natality, mortality, sex ratio, age distribution, biotic potential, and spatial distribution.
- Explain the significance of biotic potential to the rate of population growth.
- Describe the lag, exponential growth, deceleration, and stable equilibrium phases of a population growth curve. Explain why each of these stages occurs.
- Describe how limiting factors determine the carrying capacity for a population.
- List the four categories of limiting factors.
- Recognize that humans are subject to the same forces of environmental resistance as are other organisms.
- Understand the implications of overreproduction.
- Explain how human population growth is influenced by social, theological, philosophical, and political thinking.
- Explain why the age distribution and the status and role of women affect population growth projections.
- Recognize that countries in the more-developed world are experiencing an increase in the average age of their populations.
- Recognize that most countries of the world have a rapidly growing population.
- Describe the implications of the demographic transition concept.
- Recognize that rapid population growth and poverty are linked.



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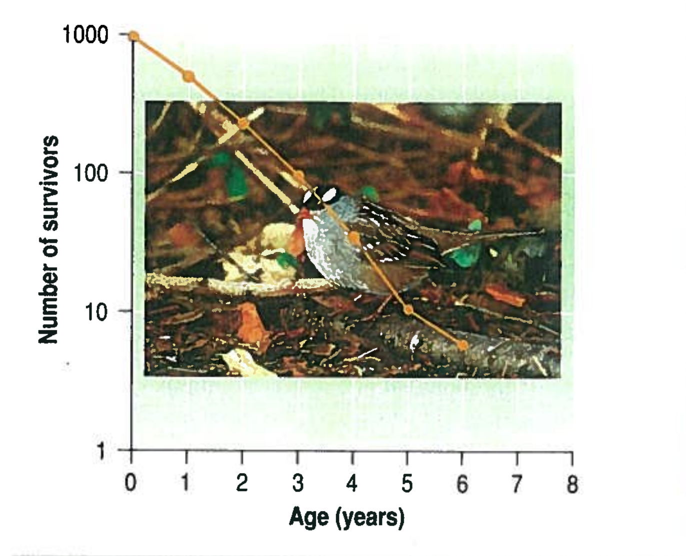

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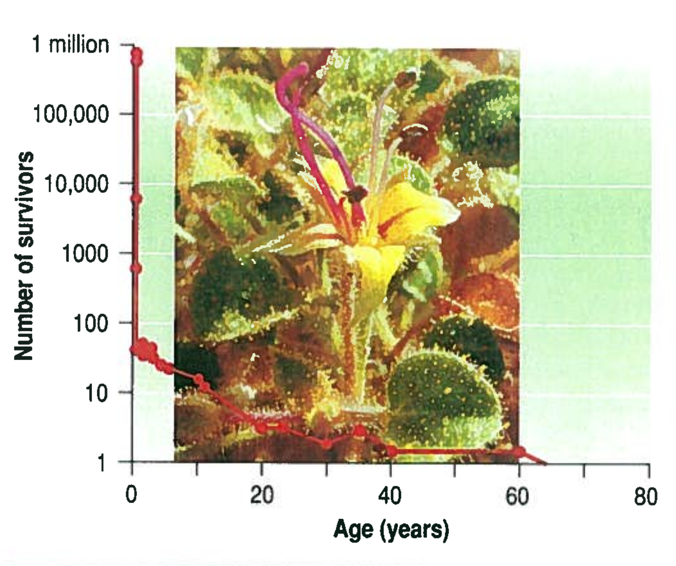


(c)

FIGURE 7.2 **Types of Survivorship Curves** (a) The Dall sheep is a large mammal that produces relatively few young. Most of the young survive, and survival is high until individuals reach old age, when they are more susceptible to predation and disease. (b) The curve shown for the white-crowned sparrow is typical of that for many kinds of birds. After a period of high mortality among the young, the mortality rate is about equal for all ages of adult birds. (c) Many small animals and plants, such as the Mediterranean shrub *Cleome droserifolia,* produce enormous numbers of offspring. Mortality is very high in the younger individuals, and few individuals reach old age.

Another way to view mortality is to view how likely it is that an offspring will survive to a specific age. One way of visualizing this is with a survivorship curve. A **survivorship curve** shows the proportion of individuals likely to survive to each age. While each species is different, three general types of survivorship curves can be recognized: species that have high mortality among their young, species in which mortality is evenly spread over all age groups, and species in which survival is high until old age, when mortality is high. Figure 7.2 gives examples of species that fit these three general categories.

Population Growth Rate

The **population growth rate** is the birthrate minus the death rate. In human population studies, the population growth rate is usually expressed as a percentage of the total population. For example, in the United States, the birthrate is 14 births per thousand individuals in the population. The death rate is 8 per thousand. The difference between the two is 6 per thousand, which is equal to an annual population increase of 0.6 percent (6/1000).

Sex Ratio

The population growth rate is greatly influenced by the sex ratio of the population. The **sex ratio** refers to the relative numbers of males and females. (Many kinds of organisms, such as earthworms and most plants, have both kinds of sex organs in the same body; sex ratio has no meaning for these species.) The number of females is very important, since they ultimately determine the number of offspring produced in the population. In polygamous species, one male may mate with many females. Therefore, the number of males is less important to the population growth rate than the number of females. In monogamous species, a male and female pair up, mate, and raise their young together. Unpaired females are not likely to be fertilized and raise young. Even if an unpaired female is fertilized, she will be less successful in raising young.

It is typical in most species that the sex ratio is about 1:1 (one female to one male). However, there are populations in which this is not true. In populations of many species of game animals, the males are shot (have a higher mortality) and the females are not. This results in an uneven sex ratio in which the females outnumber the males. In many social insect populations (bees, ants, and wasps), the number of females greatly exceeds the number of males at all times, though most of the females are sterile. In humans, about 106 males are born for every 100 females. However, in the United States, by the time people reach their mid-twenties, a higher death rate for males has equalized the sex ratio. The higher male death rate continues into old age, when women outnumber men.

Age Distribution

The **age distribution** is the number of individuals of each age in the population. Age distribution greatly influences the population growth rate. As you can see in figure 7.3, some are prereproductive juveniles, some are reproducing adults, and some are postreproductive adults. If the population has a large number of prereproductive juveniles, it would be expected to grow in the future as the young become sexually mature. If the majority of a population is made up of reproducing adults, the population should be growing. If the population is made up of old individuals whose reproductive success is low, the population is likely to fall.

Many species, particularly those that have short life spans, have age distributions that change significantly during the course of a year. Species typically produce their young during specific parts of the year. Annual plants (those that live for only one year) produce seeds that germinate in the spring or following a rainy period of the year. Therefore, during one part of the year, most of the individuals are newly germinated seeds and are prereproductive. As time passes, nearly all of those seedlings that survive become reproducing adults and produce seeds. Later in the year, they all die. A similar pattern is seen in many insects that go through their entire life cycle in a year. They emerge from eggs as larvae, transform into adults, mate and lay eggs, and die. Animals that live for several years typically produce their young at a time when food is abundant. In northern climates, this is generally in the spring of the year. In regions where rainfall is sporadic (deserts) or highly seasonal (savannas and some forests), the production of offspring usually occurs following rain. Thus, there is a surge in the number of prereproductive individuals at specific times of the year.

In species that live a long time, it is possible for a population to have an age distribution in which the proportion of individuals in these three categories is relatively constant. Since mortality is generally higher among young individuals, such populations typically have more prereproductive individuals than reproductive individuals and more reproductive individuals than postreproductive individuals.

Human populations exhibit several types of age distribution. (See figure 7.3.) Kenya's population has a large prereproductive and reproductive component. This means that it will continue to increase rapidly for some time. The United States has a very large reproductive component with a declining number of prereproductive individuals. Eventually, if there were no immigration, the U.S. population would begin to decline if current trends in birthrates and death rates continued. Italy has an age distribution with high postreproductive

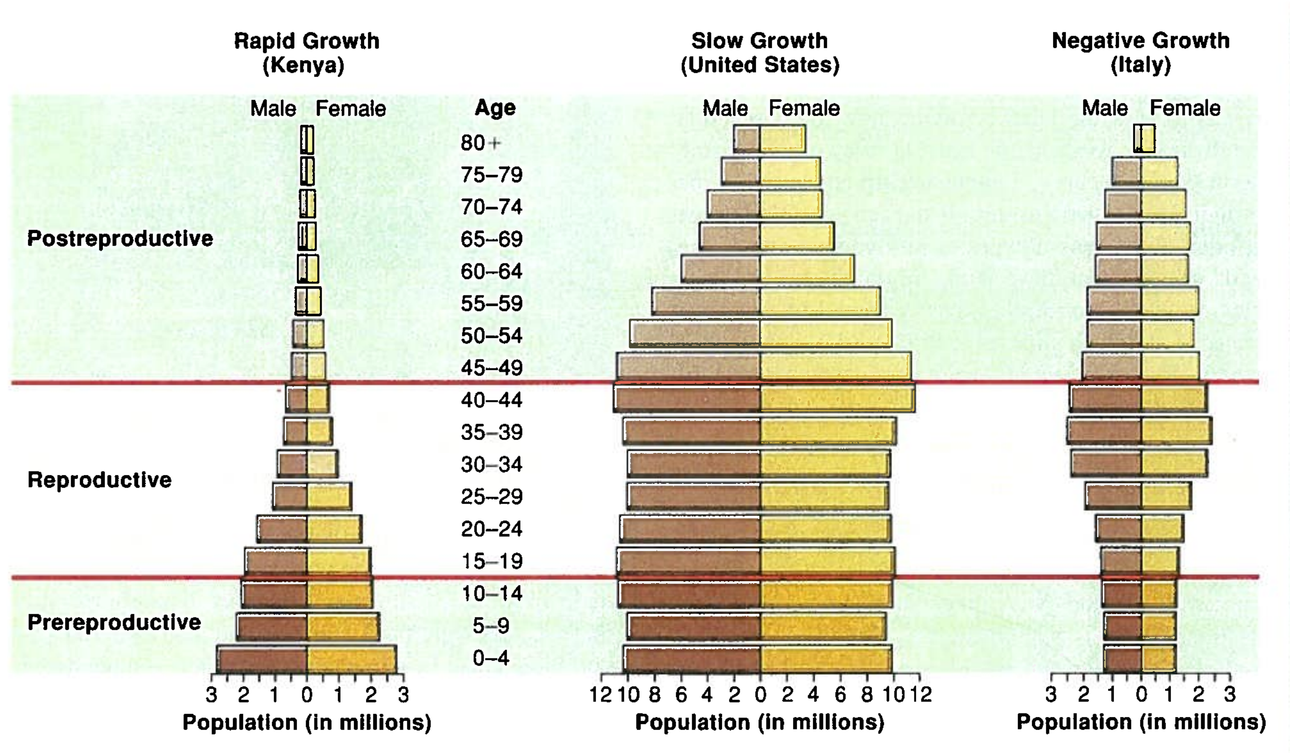


FIGURE 7.3 **Age Distribution in Human Populations** The relative numbers of individuals in each of the three categories (prereproductive, reproductive, and postreproductive) are good clues to the future growth of a population. Kenya has a large number of young individuals who will become reproducing adults. Therefore, this population is likely to grow rapidly. The United States has a large proportion of reproductive individuals and a moderate number of prereproductive individuals. Therefore, the population is likely to grow slowly. Italy has a declining number of reproductive individuals and a very small number of prereproductive individuals. Therefore, its population has begun to decline.

Source: Data from United States Census Bureau International Data Base.

and low prereproductive portions of the population. With low numbers of prereproductive individuals entering their reproductive years, the population of Italy has begun to decline.

Population Density and Spatial Distribution

Because of such factors as soil type, quality of habitat, and availability of water, organisms normally are distributed unevenly. Some populations have many individuals clustered into a small space, while other populations of the same species may be widely dispersed. **Population density** is the number of organisms per unit area. For example, fruitfly populations are very dense around a source of rotting fruit, while they are rare in other places. Similarly, humans are often clustered into dense concentrations we call cities, with lower densities in rural areas.

When the population density is too great, all individuals within the population are injured because they compete severely with each other for necessary resources. Plants may compete for water, soil nutrients, or sunlight. Animals may compete for food, shelter, or nesting sites. In animal populations, overcrowding might cause some individuals to explore and migrate into new areas. This movement from densely populated locations to new areas is called **dispersal.** It relieves the overcrowded conditions in the home area and, at the same time, increases the population in the places to which they migrate. Often, it is juvenile individuals that relieve overcrowding by leaving. The pressure to migrate from a population **(emigration)** may be a result of seasonal reproduction leading to a rapid increase in population size or environmental changes that intensify competition among members of the same species. For example, as water holes dry up, competition for water increases, and many desert birds emigrate to areas where water is still available.

The organisms that leave one population often become members of a different population. This migration into an area **(immigration)** may introduce characteristics that were not in the population originally. When Europeans immigrated to North America, they brought genetic and cultural characteristics that had a tremendous impact on the existing Native American population. Among other things, Europeans brought diseases that were foreign to the Native Americans. These diseases increased the death rate and lowered the birthrate of Native Americans, resulting in a sharp decrease in the size of their populations.

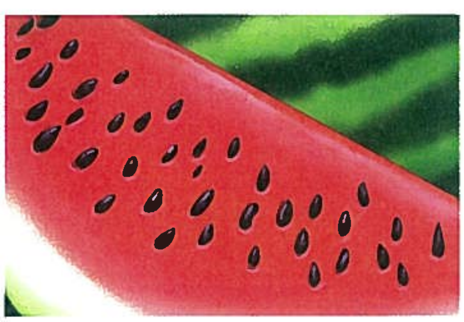
Summary of Factors that Influence Population Growth Rates

Populations have an inherent tendency to increase in size. However, as we have just seen, many factors influence the rate at which a population can grow. At the simplest level, the rate of increase is determined by subtracting the number of individuals leaving the population from the number entering. Individuals leave the population either by death or emigration. Individuals enter the population by birth or immigration. Birthrates and death rates are influenced by several factors, including the number of females in the population and their age. In addition, the density of a population may encourage individuals to leave because of intense competition for a limited supply of resources.

A Population Growth Curve

Each species has a **biotic potential** or inherent reproductive capacity, which is its biological ability to produce offspring. Reproducing individuals of some species, such as watermelon plants or moths, may produce hundreds or thousands of offspring (seeds or caterpillars) per year, while others, such as geese, may produce 10 to 12 young per year. (See figure 7.4.) Some large animals, such as bears or elephants, may produce one young every two to three years. Although there are large differences among species, generally, adults produce many more offspring during their lifetimes than are needed to replace themselves when they die. However, among organisms that produce large numbers of offspring, most of the young die, so only a few survive to become reproductive adults themselves.

Because most species have a high biotic potential, there is a natural tendency for populations to increase. If we consider a hypothetical situation in which mortality is not a factor, we could have the following situation. If two mice produced four offspring and they all lived, eventually they would produce offspring of their own, while their parents continued to reproduce as well.


Watermelon offspring (seeds)


Moth offspring (caterpillars)

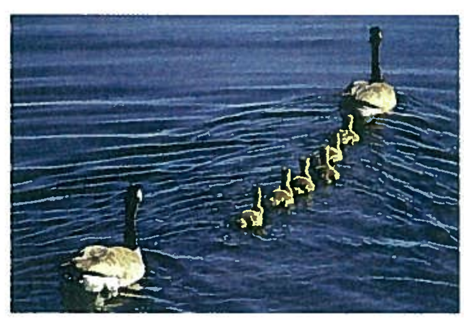

Geese

FIGURE 7.4 **Biotic Potential** The ability of a species to reproduce greatly exceeds the number necessary to replace those who die. Here are some examples of the prodigious reproductive abilities of some species.

$A_t = A_0 e^{+kt}$

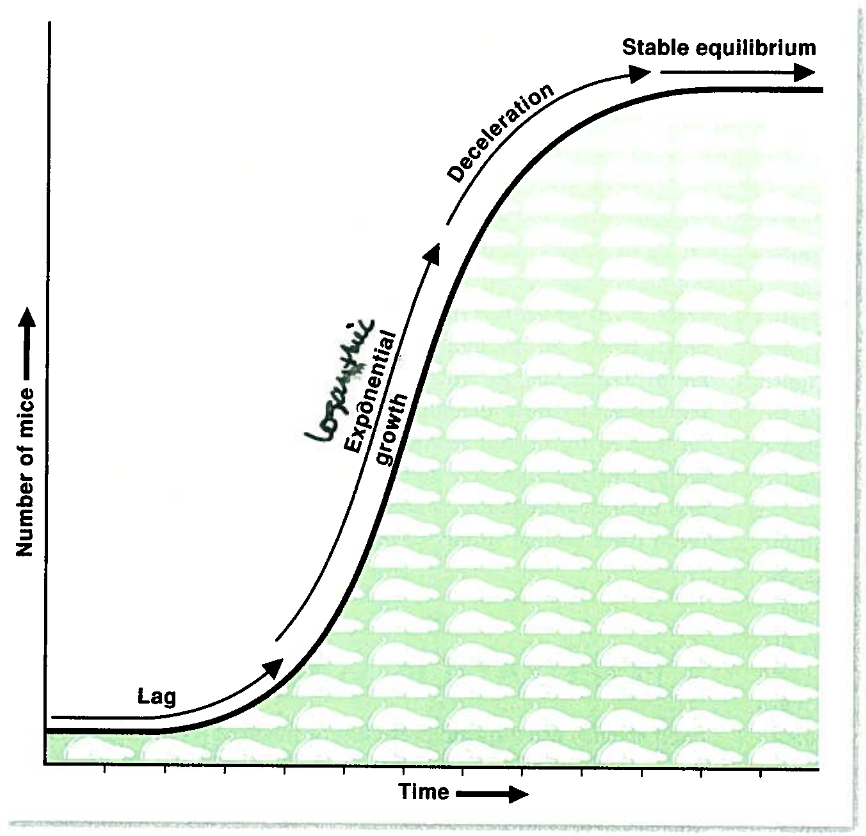


FIGURE 7.5 **A Typical Population Growth Curve** In this mouse population, there is little growth during the lag phase. During the exponential growth phase, the population rises rapidly as increasing numbers of individuals reach reproductive age. Eventually, the population growth rate begins to slow during the deceleration phase and the population reaches a stable equilibrium phase, during which the birthrate equals the death rate.

Under these conditions, the population will grow exponentially. Exponential growth results in a population increasing by the same percentage each year. For example, if the population were to double each year, we would have 2, 4, 8, 16, 32, etc. individuals in the population. While populations cannot grow exponentially forever, they often have an exponential period of growth.

Population growth often follows a particular pattern, consisting of a lag phase, an exponential growth phase, a deceleration phase, and a stable equilibrium phase. Figure 7.5 shows a typical population growth curve. During the first portion of the curve, known as the **lag phase,** the population grows very slowly because there are few births, since the process of reproduction and growth of offspring takes time. Organisms must mature into adults before they can reproduce. While the offspring begin to mate and have young, the parents may be producing a second set of offspring. Since more organisms now are reproducing, the population begins to increase at an accelerating rate. This stage is known as the **exponential growth phase (log phase).** The population will continue to grow as long as the birthrate exceeds the death rate. Eventually, however, the population growth rate will begin to slow as the death rate and the birthrate come to equal one another. This is the **deceleration phase.** When the birthrate and death rate become equal, the population will stop growing and reach a relatively stable population size. This stage is known as the **stable equilibrium phase.**

It is important to recognize that although the size of the population may not be changing, the individuals are changing. As new individuals enter by birth or immigration, others leave by death or emigration. For most organisms, the first indication that a population is entering a stable equilibrium phase is an increase in the death rate. A decline in the birthrate may also contribute to the stabilizing of population size. Usually, this occurs after an increase in the death rate.

FACTORS THAT LIMIT POPULATION SIZE

Populations cannot continue to increase indefinitely. Eventually, some factor or set of factors acts to limit the size of a population. The factors that prevent unlimited population growth are known as **limiting factors.** All of the different limiting factors that act on a population are collectively known as **environmental resistance.**

EXTRINSIC AND INTRINSIC LIMITING FACTORS

Some factors that control populations come from outside the population and are known as **extrinsic limiting factors.** Predators, loss of a food source, lack of sunlight, or accidents of nature are all extrinsic factors. However, the populations of many kinds of organisms appear to be regulated by factors from within the populations themselves. Such limiting factors are called **intrinsic limiting factors.** For example, a study of rats under crowded living conditions showed that as conditions became more crowded, abnormal social behavior became common. There was a decrease in litter size, fewer litters per year were produced, mothers were more likely to ignore their young, and adults killed many young. Thus changes in the behavior of the members of the rat population itself resulted in lower birthrates and higher death rates that limit population size. Among populations of white-tailed deer, it is well known that reproductive success is reduced when the deer experience a series of severe winters. When times are bad, the female deer are more likely to have single offspring than twins.

DENSITY-DEPENDENT AND DENSITY-INDEPENDENT LIMITING FACTORS

Density-dependent limiting factors are those that become more effective as the density of the population increases. For example, the larger a population becomes, the more likely it is that predators will have a chance to catch some of the individuals. A prolonged period of increasing population allows the size of the predator population to increase as well. Disease epidemics are also more common in large, dense populations because dense populations allow for the easy spread of parasites from one individual to another. The rat example discussed previously is another good example of a density-dependent factor operating because the amount of abnormal behavior increased as the density of the population increased. In general, whenever there is competition among members of a population, its intensity increases as the population density increases. Large organisms that tend to live a long time and have relatively few young are most likely to be controlled by density-dependent factors.

Density-independent limiting factors are population-controlling influences that are not related to the density of the population. They are usually accidental or occasional extrinsic factors in nature that happen regardless of the density of a population. A sudden rainstorm may drown many small plant seedlings and soil organisms. Many plants and animals are killed by frosts that come late in spring or early in the fall. A small pond may dry up, resulting in the death of many organisms. The organisms most likely to be controlled by density-independent factors are small, short-lived organisms that can reproduce very rapidly.

CATEGORIES OF LIMITING FACTORS

For most populations, limiting factors recognized as components of environmental resistance can be placed into four broad categories: (1) the availability of raw materials, (2) the availability of energy, (3) the accumulation of waste products, and (4) interactions among organisms.

AVAILABILITY OF RAW MATERIALS

Raw materials come in many forms. For example, plants need nitrogen and magnesium from the soil as raw materials for the manufacture of chlorophyll. If these minerals are not present in sufficient quantities, the plant population cannot increase. The application of fertilizers is a way of preventing certain raw materials from being a limiting factor. In effect, the carrying capacity has been increased because this limiting factor has been removed. A carrying capacity still exists, but it is set at a new level, and some new primary limiting factor will emerge. Perhaps it will be the amount of water, the number of insects that feed on the plants, or competition for sunlight. Animals also require certain minerals as raw material, which they obtain in their diets. They may also require objects with which to build nests, to provide places for escape, or to serve as observation sites.

AVAILABILITY OF ENERGY

Energy sources are important to all organisms. Plants require energy in the form of sunlight for photosynthesis, so the amount of light can be a limiting factor for many plants. When small plants are in the shade of trees, they often do not grow well and have small populations because they do not receive enough sunlight. Animals require energy in the form of the food they eat, and if food is scarce, many die.

ACCUMULATION OF WASTE PRODUCTS

The accumulation of waste products is not normally a limiting factor for plants, since they produce few wastes, but it can be for other kinds of organisms. Bacteria, other tiny organisms, and many kinds of aquatic organisms that live in small ecosystems such as puddles, pools, or aquariums may be limited by wastes. When a small number of a species of bacterium are placed on a petri plate with nutrient agar (a jellylike material containing food substances), the population growth follows a curve shown in figure 7.6. As expected, it begins with a lag phase, continues through an exponential growth phase, and eventually levels off in a stable equilibrium phase. However, in this small, enclosed space, there is no way to get rid of the toxic waste products, which accumulate, eventually killing the bacteria. This decline in population size is known as the **death phase.**

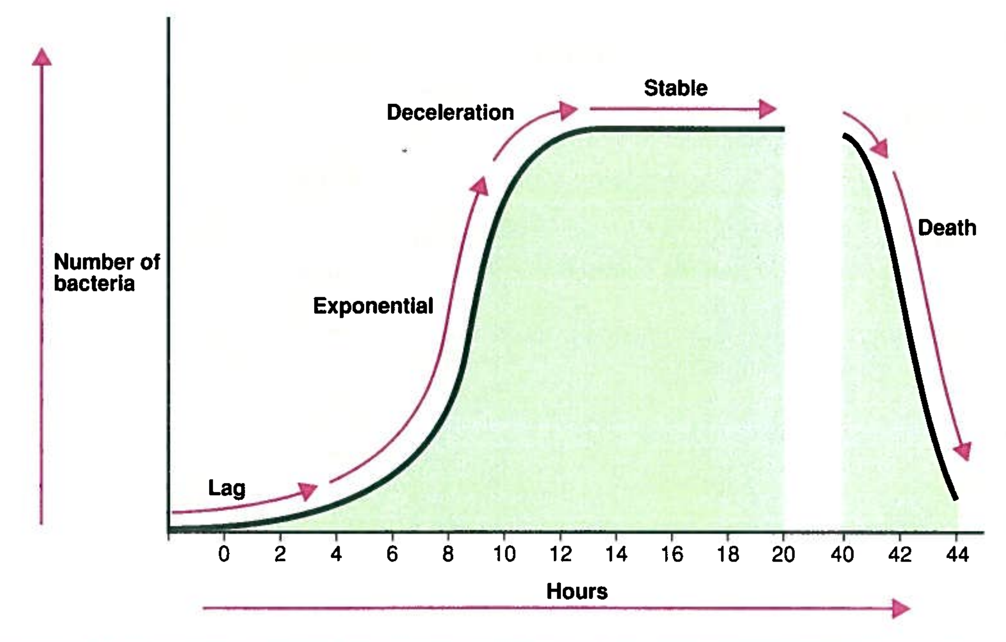


FIGURE 7.6 **A Bacterial Growth Curve** The initial change in population size follows a typical population growth curve until waste products become lethal. The buildup of waste products lowers the carrying capacity. When a population begins to decline, it enters the death phase.

INTERACTIONS AMONG ORGANISMS

Interactions among organisms are also important in determining population size. For example, white-tailed deer and cottontail rabbits eat the twigs of many species of small trees and shrubs. Repeated browsing by herbivores retards growth and can cause death of trees and shrubs. Thus, damage by herbivores can limit the size of some tree and shrub populations. Many single-celled aquatic organisms produce waste products that build up to toxic levels and result in the death of fish. Parasites and predators weaken or cause the premature death of individuals, thus limiting the size of the population.

Some studies indicate that populations can be controlled by interaction among individuals within the population. A study of laboratory rats shows that crowding causes a breakdown in normal social behavior, which leads to fewer births and increased deaths. The changes observed include abnormal mating behavior, decreased litter size, fewer litters per year, lack of maternal care, and increased aggression in some rats or withdrawal in others. Thus, limiting factors can reduce birthrates as well as increase death rates. Many other kinds of animals have shown similar reductions in breeding success when population densities were high.

CARRYING CAPACITY

The populations of many organisms are at their maximum size when they reach the stable equilibrium phase. This suggests that the environment sets an upper limit to the size of the population. Ecologists have developed a concept for this observation, called the *carrying capacity*. **Carrying capacity** is the maximum sustainable population for an area. The carrying capacity is determined by a set of limiting factors. (See figure 7.7.)

Carrying capacity is not an inflexible number, however. Often such environmental differences as successional changes, climate variations, disease epidemics, forest fires, or floods can change the carrying capacity of an area for specific species. In aquatic ecosystems one of the major factors that determine the carrying capacity is the amount of nutrients in the water. In areas where nutrients are abundant, the numbers of various kinds of organisms are high. Often nutrient levels fluctuate with changes in current or runoff from the land, and plant and animal populations fluctuate as well. In addition, a change that negatively affects the carrying capacity for one species may increase the carrying capacity for another. For example, the cutting down of a mature forest followed by the growth of young trees increases the carrying capacity for deer and rabbits, which use the new growth for food, but decreases the carrying capacity for squirrels, which need mature, fruit-producing trees as a source of food and old, hollow trees for shelter.

Wildlife management practices often encourage modifications to the environment that will increase the carrying capacity for the designated game species. The goal of wildlife managers is to have the highest sustainable population available for harvest by hunters. Typical habitat modifications include creating water holes, cutting forests to provide young growth, planting food plots, and building artificial nesting sites.

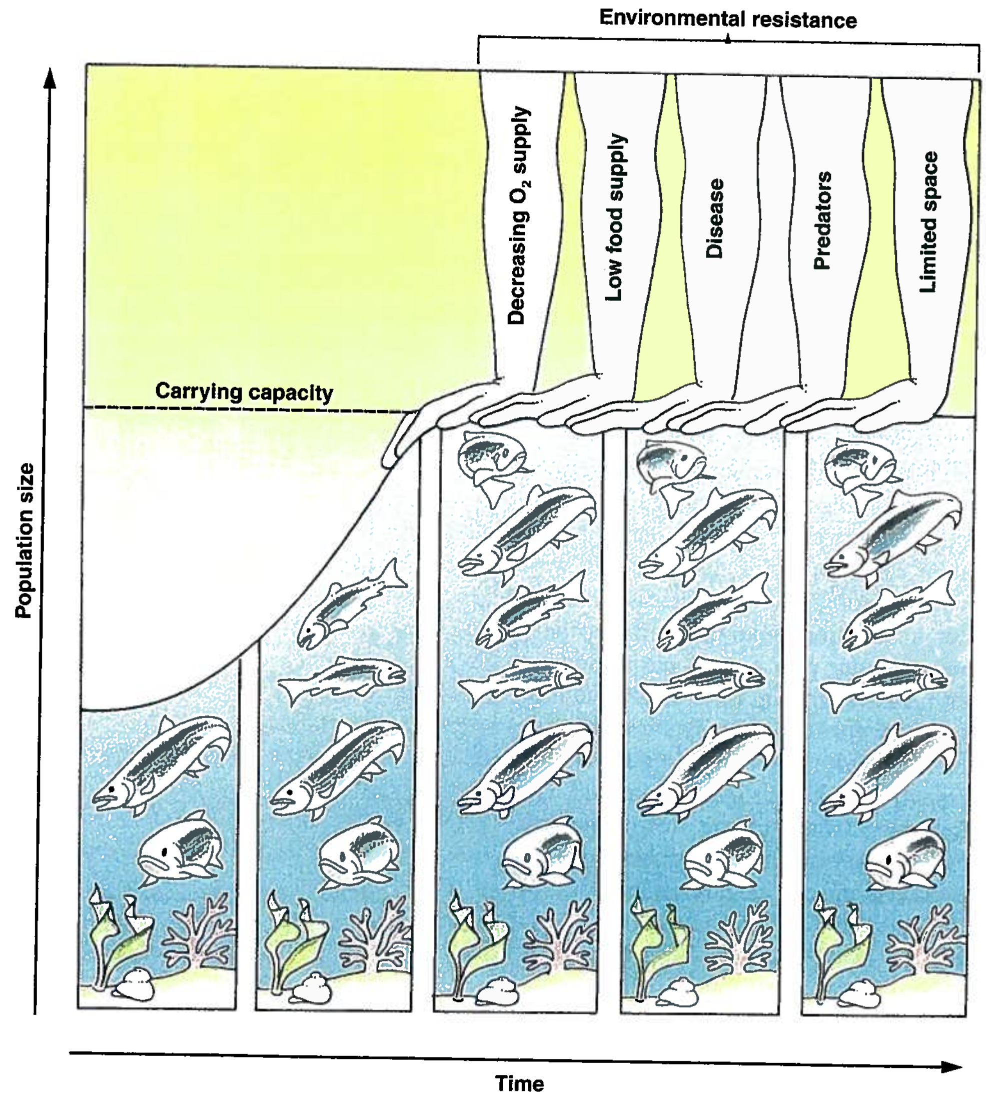


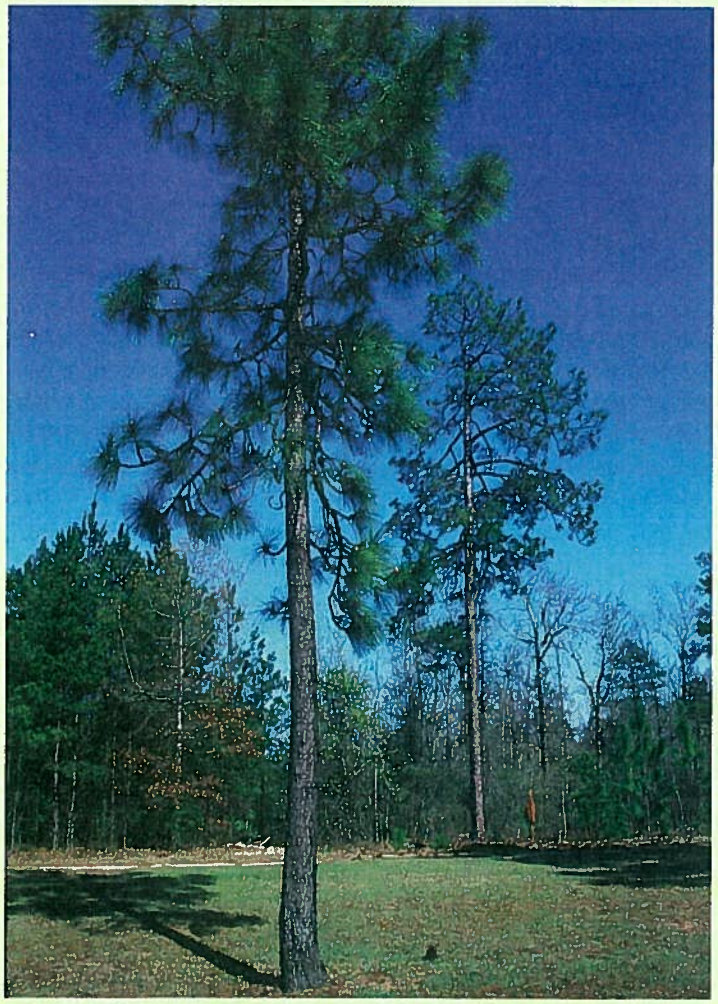
FIGURE 7.7 **Carrying Capacity** A number of factors in the environment, such as oxygen supply, food supply, diseases, predators, and space, determine the number of organisms that can survive in a given area—the carrying capacity of that area. The environmental factors that limit populations are known collectively as environmental resistance.

Going Green

Increasing Populations of Red-Cockaded Woodpeckers

The red-cockaded woodpecker (*Picoides borealis*) is listed as an endangered species. This medium-sized bird (about the size of a cardinal) is a cooperative colony nester—the dominant male and female raise young with the support of nonbreeding members of the colony. They are only found in the southeastern United States—southern Virginia to eastern Texas—where native southern yellow pine forests occur. Several pine species, including slash pine, shortleaf pine, loblolly pine, and longleaf pine, are typical of this region. The original forests were fire-adapted in that mature trees were able to withstand moderate ground fires. This resulted in a rather open forest type. The woodpeckers typically construct their nesting cavities in older, diseased longleaf pine trees.

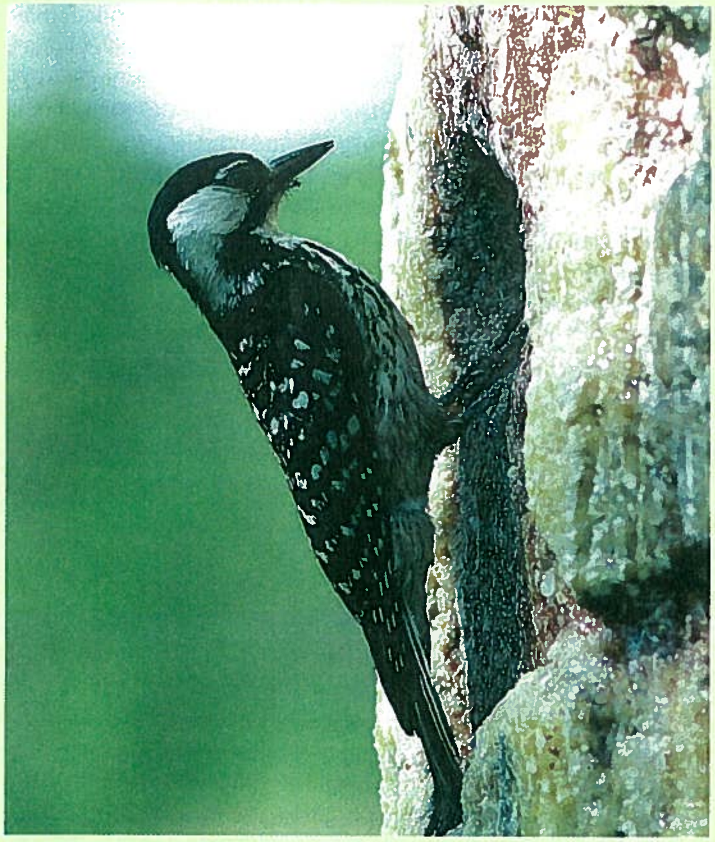
The trees these birds use for nesting are also commercially important. Thus, the amount of suitable breeding habitat has been severely reduced as older trees are harvested and natural stands of pines have been replaced with plantations, where large tracts are planted to a single species and the trees are harvested before they reach old age.



Red-cockaded woodpecker habitat

Since much of the suitable habitat is privately owned, protecting populations of red-cockaded woodpeckers requires the cooperation of private landowners, conservation organizations, state and federal governments, and commercial forest products companies.

In 1998, International Paper entered into an agreement with the U.S Fish and Wildlife Service, which is responsible for monitoring the status of endangered species, to increase the amount of suitable nesting habitat on its lands. International Paper agreed to set aside particular parcels of forest to maintain colonies of red-cockaded woodpeckers. One of those parcels was the Southlands Experimental Forest near Bainbridge, Georgia. When the agreement was signed in 1998, there were three male red-cockaded woodpeckers at the site. By 2008, there were over 50 individuals. The increase is attributable to protection and improvement of the birds' habitat and transfer of birds to the area from other locations. In 2006, the company decided to sell nearly all of its land holdings in the United States. Many environmentally sensitive lands were sold to conservation organizations such as The Nature Conservancy and the Conservation Fund, as well as state governments. The Southlands Experimental Forest was sold to the state of Georgia with some funding assistance from the Conservation Fund. This land transfer protects the population gains made by this population of red-cockaded woodpeckers.



Red-cockaded woodpecker

VERHULST EQUATION: $\frac{\Delta N}{\Delta t} = rN\left(1 - \frac{N}{K}\right)$ n.b. as $\frac{N}{K} \to 1$, $\Delta N/\Delta t \to 0$

REPRODUCTIVE STRATEGIES AND POPULATION FLUCTUATIONS

So far, we have talked about population growth as if all organisms reach a stable population when they reach the carrying capacity. That is an appropriate way to begin to understand population changes, but the real world is much more complicated.

K-Strategists and r-Strategists

Species can be divided into two broad categories based on their reproductive strategies. **K-strategists** are organisms that typically reach a stable population as the population reaches the carrying capacity. K-strategists usually occupy relatively stable environments and tend to be large organisms that have relatively long lives, produce few offspring, and provide care for their offspring. Their reproductive strategy is to invest a great deal of energy in producing a few offspring that have a good chance of living to reproduce. Deer, lions, and swans are examples of this kind of organism. Humans generally produce single offspring, and even in countries with high infant mortality, 80 percent of the children survive beyond one year of age, and the majority of these will reach adulthood. Generally, populations of K-strategists are controlled by density-dependent limiting factors that become more severe as the size of the population increases. For example, as the size of the hawk population increases, the competition among hawks for available food becomes more severe. The increased competition for food is a density-dependent limiting factor that leads to less food for the young in the nest. Therefore, many of the young die, and population growth rate slows as the carrying capacity for the area is reached.

The **r-strategists** are typically small organisms that have a short life, produce many offspring, exploit unstable environments, and do not reach a carrying capacity. Examples are bacteria, protozoa, many insects, and some small mammals. The reproductive strategy of r-strategists is to expend large amounts of energy producing many offspring but to provide limited care (often none) for them. Consequently, there is high mortality among the young. For example, one female oyster may produce a million eggs, but of those that become fertilized and grow into larvae, only a few find suitable places to attach themselves and grow into mature oysters. Typically, populations of r-strategists are limited by density-independent limiting factors. These factors can include changing weather conditions that kill large numbers of organisms, habitat loss such as occurs when a pond dries up or fire destroys a forest, or an event such as a deep snow or flood that buries sources of food and leads to the death of entire populations. The population size of r-strategists is likely to fluctuate wildly. They reproduce rapidly, and the size of the population increases until some density-independent factor causes the population to crash; then they begin the cycle all over again. (See figure 7.8.)

The concepts of K- or r-strategists describe idealized situations. (See table 7.1.) (The letters *K* and *r* in *K-strategists* and *r-strategists* come from a mathematical equation in which *K* represents the carrying capacity of the environment and *r* represents the biotic potential of the species.) In the real world many organisms don't fit clearly into either category. For example, many kinds of mammals provide care for their offspring but have short life spans. On the other hand, many reptiles such as turtles may live for many years, but they produce large numbers of eggs and do not care for them.

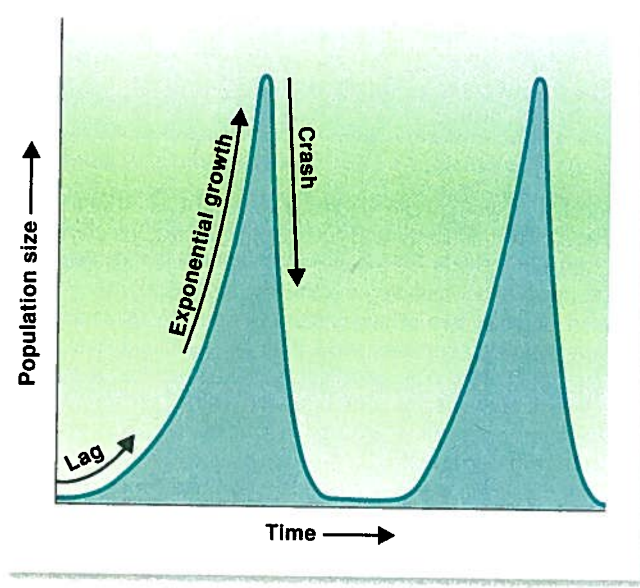


FIGURE 7.8 A Population Growth Curve for Short-Lived Organisms Organisms that are small and only live a short time often have the kind of population growth curve shown here. There is a lag phase followed by an exponential growth phase. However, instead of entering into a stable equilibrium phase, the population reaches a maximum and crashes.

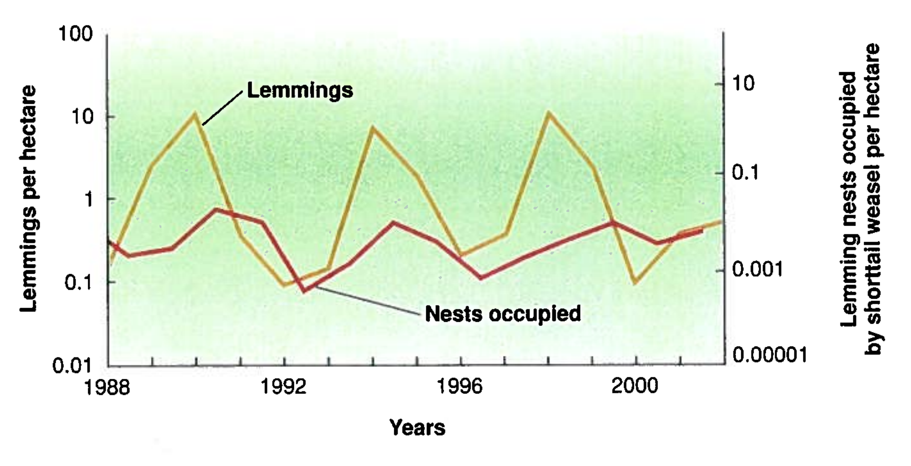
TABLE 7.1 A Comparison of Life History Characteristics of Typical K- and r-Strategists

Characteristic	K-Strategist	r-Strategist
Environmental stability	Stable	Unstable
Size of organism	Large	Small
Length of life	Long, most live to reproduce	Short, most die before reproducing
Number of offspring	Small number produced, parental care provided	Large number produced, no parental care
Primary limiting factors	Density-dependent limiting factors	Density-independent limiting factors
Population growth pattern	Exponential growth followed by a stable equilibrium stage at the carrying capacity	Exponential growth followed by a population crash
Examples	Alligators, humans, redwood trees	Protozoa, mosquitoes, annual plants

r: less crowded ∴ $\frac{N}{K} \to 0$ ∴ $\frac{dN}{dt} = rN$ | K: competitive, care for offspring.

FIGURE 7.9 Population Cycles In many northern regions of the world, population cycles are common. In the case of collared lemmings and shorttail weasels on Greenland, interactions between the two populations result in population cycles of about four years. The graph shows the population of lemmings per hectare and the number of lemming nests occupied by weasels per hectare. A hectare is 10,000 square meters—about 2.47 acres. The researchers used the number of lemming nests occupied by weasels as an indirect measure of the size of the weasel population because of difficulties in measuring the size of the weasel population by other means.

Source: Data from O. Gilg, I. Hamski, and B. Sittler, "Cyclic Dynamics in a Simple Predator-Prey Community," *Transpol'air* Online Magazine, www.transpolair.com.



$$\frac{dN}{dt} = rN\left(1 - \frac{N}{K}\right)$$

r = growth rate N = population K = carrying capacity

Since humans are K-strategists, it may be difficult for us to appreciate that the r-strategy can be viable from an evolutionary point of view. Resources that are present only for a short time can be exploited most effectively if many individuals of one species monopolize the resource, while denying other species access to it. Rapid reproduction can place a species in a position to compete against other species that are not able to increase numbers as rapidly. Obviously, most of the individuals will die, but not before they have left some offspring or resistant stages that will be capable of exploiting the resource should it become available again.

Even K-strategists, however, have some fluctuations in their population size for a variety of reasons. One reason is that even in relatively stable ecosystems, there will be variations from year to year. Floods, droughts, fires, extreme cold, and similar events may affect the carrying capacity of an area, thus causing fluctuations in population size. Epidemic disease or increased predation may also lead to populations that vary in size from year to year. Many endangered species have reduced populations because their normal environment has been altered either naturally or as a result of human activity. (See chapter 11 on biodiversity issues.)

Population Cycles

In northern regions of the world, many kinds of animals show distinct population cycles—periods of relatively large populations followed by periods of small populations. This is generally thought to be the case because the ecosystems are relatively simple, with few kinds of organisms affecting one another. Many of these cycles are quite regular. Biologists have been studying these cycles since the 1920s, and they have developed several theories about why northern populations cycle.

One idea is that heavy feeding by large populations of herbivores causes the plants to produce increased amounts of chemicals, which taste bad or are toxic. A second thought is that when an herbivore population is large, many different predators shift to eating them and the herbivore population crashes. Another idea is that interactions between a prey organism and a specialized predator naturally lead to population cycles. The length of the population cycle depends on the reproductive biology of the prey and their predators.

A study of the population biology of the collared lemming (*Dicrostonyx groenlandicus*) on Greenland illustrates the population interactions between lemmings and four different predators. Lemmings have a very high biotic potential. They produce two to three litters of young per year. Their population is held in check by four different predators. Three of these predators—the snowy owl, arctic fox, and longtailed skua (a bird that resembles a gull)—are generalist predators whose consumption of lemmings is directly related to the size of the lemming population. They constitute a density-dependent limiting factor for the lemming population. When lemming numbers are low, these predators seek other prey. For example, the snowy owl often migrates to other regions when lemming numbers are low in a particular region. The fourth predator is the shorttail weasel (*Mustela ermina*), a specialist predator on lemmings. The weasels are much more dependent on lemmings for food than the other predators. Since the weasels mate once a year, their populations increase at a slower rate than those of the lemmings. As weasel populations increase, however, they eventually become large enough that they drive down the lemming populations. The resulting decrease in lemmings leads to a decline in the number of weasels, which allows greater survival of lemmings, which ultimately leads to another cycle of increased weasel numbers. (See figure 7.9.)

HUMAN POPULATION GROWTH

The human population growth curve has a long lag phase followed by a sharply rising exponential growth phase that is still rapidly increasing. (See figure 7.10.) A major reason for the continuing increase in the size of the human population is that the human species has lowered its death rate. When various countries reduce environmental resistance by increasing food production or controlling disease, they share this technology throughout the world. Developed countries send health care personnel to all parts of the globe to improve the quality of life for people in less-developed countries. Physicians offer advice on nutrition, and engineers develop wastewater treatment systems. Improved sanitary facilities in India and

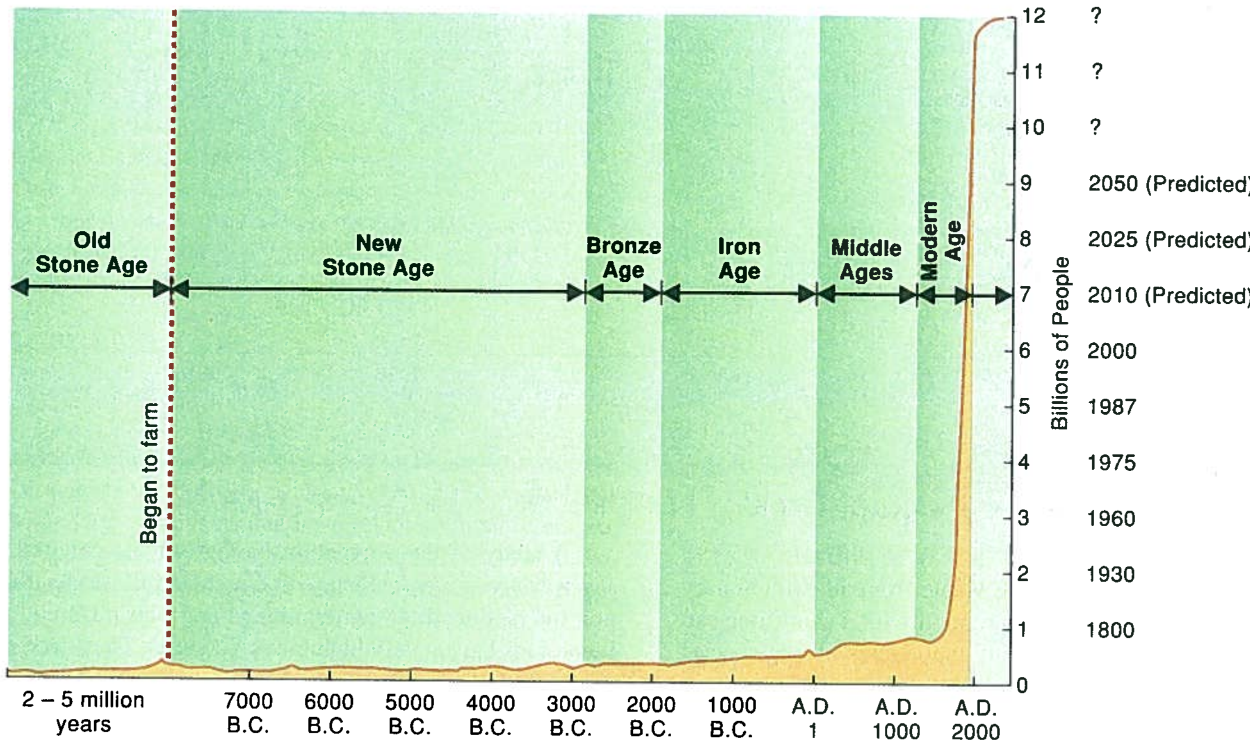


FIGURE 7.10 **The Historical Human Population Curve** From A.D. 1800 to A.D. 1930, the number of humans doubled (from 1 billion to 2 billion) and then doubled again by 1975 (4 billion) and is projected to double again (8 billion) by the year 2025. How long can this pattern continue before the Earth's ultimate carrying capacity is reached?

Source: Data from Jean Van Det Tak, et al., "Our Population Predicament: A New Look," *Population Bulletin,* vol. 34, no. 5 (December 1979), Population Reference Bureau, Washington, D.C.: and more recent data from the Population Reference Bureau.

Indonesia, for example, decreased deaths caused by cholera. These advancements tend to reduce death rates while birthrates remain high. Thus, the size of the human population increases rapidly.

Let us examine the human population situation from a different perspective. The world population is currently increasing at an annual rate of 1.2 percent. That may not seem like much, but even at 1.2 percent, the population is growing rapidly. It can be difficult to comprehend the impact of a 1 or 2 percent annual increase. Remember that a growth rate in any population compounds itself, since many of the additional individuals eventually reproduce, thus adding more individuals. One way to look at this growth is to determine how much time is needed to double the population. This is a valuable method because most of us can appreciate what life would be like if the number of people in our locality were doubled, particularly if the doubling were to occur within our lifetime.

Figure 7.11 shows the relationship between the rate of annual increase for the human population and the number of years it would take to double the population if that rate were to continue.

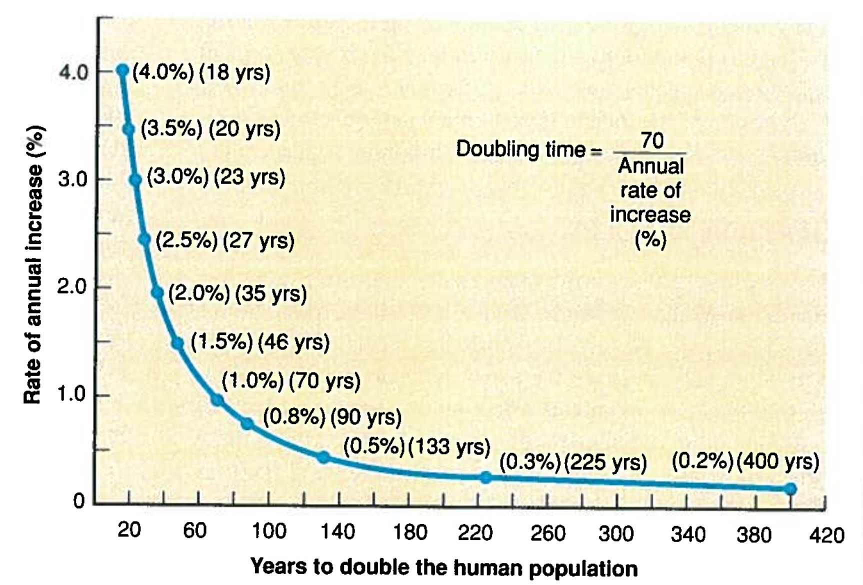


FIGURE 7.11 **Doubling Time for the Human Population** This graph shows the relationship between the rate of annual increase in percent and doubling time. A population growth rate of 1 percent per year would result in the doubling of the population in about 70 years. A population growth rate of 3 percent per year would result in a population doubling in about 23 years.