Populations

CHAPTER 6

Bring out every kind of living creature that is with you—the birds, the animals, and all the creatures that move along the ground—so they can multiply on the Earth and be fruitful and increase in number upon it.

—Genesis 8:16–18

POPULATION BIOLOGY CONCEPTS

Several topics must be considered when discussing population biology:

- Population ecology
- Carrying capacity (K)
- Reproductive strategies
- Survivorship

Population Ecology

Population ecology studies the dynamics of species' populations and how these populations interact with the environment. Population ecology plays an important role in the development of the field of conservation biology, especially in the development of population viability analysis (PVA). PVA allows ecologists to predict the long-term probability of a species persisting in a given habitat. The following table lists those factors that affect population viability.

Most organisms live in groups (flocks, schools, nests, and so on). Living in groups provides several advantages: increased protection from predators, increased chances for mating, and division of labor.

Factors That Affect Population Viability

Increase (+) Viability	Decrease (–) Viability
Favorable environmental conditions (light, temperature, and nutrients)	Unfavorable environmental conditions (insufficient light, temperature extremes, and/or poor supply of nutrients)
High natality	Low natality
Generalized niche	Specialized niche
Satisfactory habitat	Habitat not satisfactory or has been seriously impacted
Few competitors	Too many competitors
Suitable predatory defense mechanism(s)	Unsuitable predatory defense mechanism(s)
Adequate resistance to diseases and parasites	Little or no suitable defense mechanisms against diseases or parasites
Able to migrate	Unable to migrate
Flexible—able to adapt	Inflexible—unable to adapt
Sufficient food supply	Deficient food supply

Carrying Capacity (*K*)

Carrying capacity refers to the number of organisms that can be supported in a given area sustainably. It varies from species to species and is subject to changes over time. As an environment degrades, the carrying capacity decreases. Factors that keep population sizes in balance with the carrying capacity are called regulating factors. They include food availability, space, oxygen content in aquatic ecosystems, nutrient levels in soil profiles, and the amount of sunlight. Below the carrying capacity, populations tend to increase in size. Population size cannot be sustained above the carrying capacity; eventually the population will crash.

A population's biotic potential is the maximum rate at which a population can grow. Its biotic potential, given optimal conditions (food, water, and space), occurs when resources are unlimited. Factors that influence biotic potential include age at reproduction, frequency of reproduction, number of offspring produced, reproductive life span, and average death rate under ideal conditions. If a population in a community is left unchecked, the maximum population growth rate can increase exponentially and takes on a J-shaped curve.

Predation not only removes the very old, the very young, and the weaker members from the population, it may also reduce the population of the prey. If the predators do not keep the prey population in balance, the carrying capacity is exceeded and the prey may starve. Predator and prey populations are closely interdependent. Populations of algae, annual plants, and insects with short life spans are controlled by seasonal and nutritional environmental changes. A J-shaped growth curve may show a plunge in population as the reproductive potential declines because of environmental changes. The following year, there may be an exponential increase in the population.

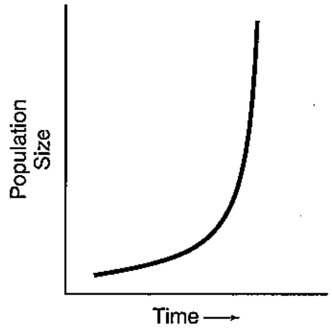


Figure 6.1 J-shaped curve

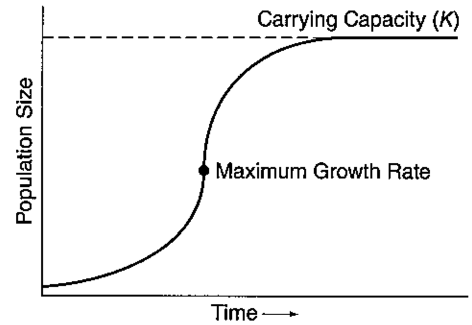


Figure 6.2 S-shaped curve (logistics model)

An S-shaped curve is used to describe the pattern of growth over extended periods of time when organisms move into an empty niche. Growth rates are density-dependent. They are characterized by maximum population growth rate and the carrying capacity. In an S-shaped curve, population size initially increases due to unlimited resources for a small population. However, as resources become limited, the population growth rate slows down and stabilizes around the limits of the carrying capacity at the point where the birth rate equals the death rate. The average American's ecological footprint (the demand of an individual with an average amount of resources) is about 12 acres.

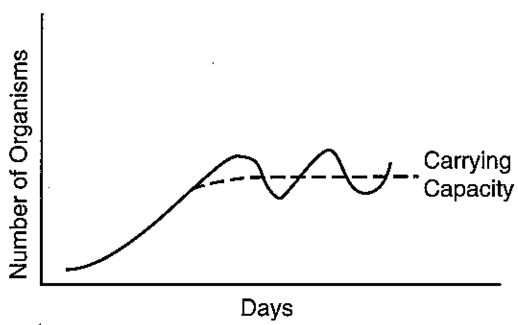


Figure 6.3 Fluctuations around the carrying capacity

Thomas Malthus

Thomas Malthus was a political economist who was concerned about what he saw as the decline of living conditions 19th-century England. He blamed this decline on three elements: (1) the overproduction of young; (2) the inability of resources to keep up with the rising human population; and (3) the irresponsibility of the lower classes. To combat this, Malthus suggested the family size of the lower class ought to be regulated such that poor families do not produce more children than they can support. In his 1798 work, *Essay on Population*, Malthus hypothesized that unchecked population growth always exceeds the means of supporting a larger population. He argued that actual population growth is kept in line with food supply by "positive checks" such as starvation and disease, which elevate the death rate, and by "preventive checks" (e.g., postponement of marriage), which keep down the birth rate. Malthus's hypothesis implied that actual population growth always has the tendency to push above the available food supply. Because of this tendency, any attempt to correct the condition of the lower classes by increasing their living standards or improving agricultural productivity would not be possible, as any extra means of subsistence would be completely absorbed by an increase in the population. Charles Darwin incorporated some of Malthus's ideas into his 1859 book, *On the Origin of Species*, by stating that limited resources result in competition, with those organisms that survive being able to pass on those adaptations through their genes to their offspring.

Reproductive Strategies

Organisms have adapted either to maximize growth rates in environments that lack limits or to maintain population size at close to the carrying capacity in stable environments. Species that have high reproductive rates are known as *r*-strategists. Species that reproduce later in life and with fewer offspring are known as *K*-strategists.

Reproductive Strategies

r-Strategists	*K*-Strategists
Mature rapidly	Mature slowly
Short lived	Long lived
Tend to be prey	Tend to be both predator and prey
Have many offspring and tend to overproduce	Have few offspring
Low parental care	High parental care
Are generally not endangered	Most endangered species are *K*-strategists
Wide fluctuations in population density (booms and busts)	Population size stabilizes near the carrying capacity
Population size limited by density-independent limiting factors, including climate, weather, natural disasters, and requirements for growth	Density-dependent limiting factors to population growth stem from intra-specific competition and include competition, predation, parasitism, and migration
Tend to be small	Tend to be larger
Type III survivorship curve	Type I or II survivorship curve
Examples: most insects, algae, bacteria, rodents, and annual plants	Examples: humans, elephants, cacti, and sharks

Survivorship

Survivorship curves show age distribution characteristics of species, reproductive strategies, and life history. Reproductive success is measured by how many organisms are able to mature and reproduce. Each survivorship curve represents a balance between natural resource limitations and interspecific and intraspecific competition. For example, humans could not survive in a Type III survivorship mode, where human females would produce thousands of offspring. Likewise, ants could not survive in a Type I mode, where each queen ant would produce only a few eggs during her lifetime and where she would spent most of her time and energy raising offspring.

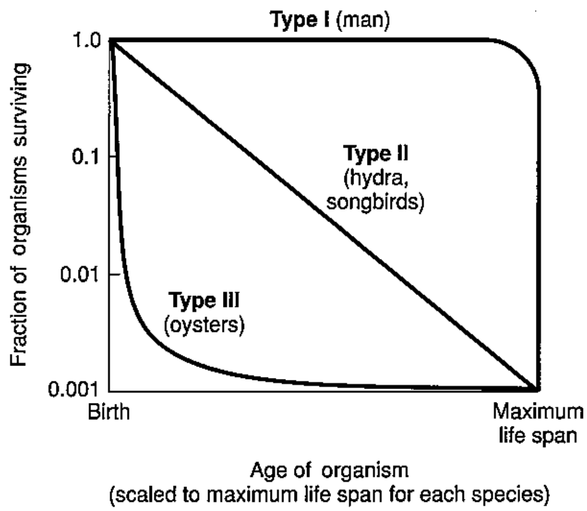


Figure 6.4 Survivorship curve

Survivorship Curves

Type	Description
I Late Loss	Reproduction occurs fairly early in life. Most deaths occur at the limit of biological life span. Low mortality at birth; high probability of surviving to advanced age. Death rates increase during old age. Advances in prenatal care, nutrition, disease prevention, and cures including immunization have meant longer life spans for humans. Examples: humans, annual plants, sheep, and elephants.
II Constant Loss	Individuals in all age categories have fairly uniform death rates. Predation affecting all age categories is primary means of death. Typical of organisms that reach adult stages quickly. Examples: rodents, perennial plants, and songbirds.
III Early Loss	Typical of species that have great numbers of offspring and reproduce for most of their lifetime. Death is prevalent for younger members of the species (environmental loss and predation) and declines with age. Examples: sea turtles, trees, internal parasites, fish, and oysters.

HUMAN POPULATION DYNAMICS

Many different factors affect the human population: historical population sizes, population distribution, fertility rates, growth rates, doubling times, and demographic transition. Age-structure diagrams act as indicators of future population trends.

Historical Population Sizes

The rapid growth of the world's human population over the past 100 years has been due primarily to a decrease in death rates. In 1900, the overall death rate in the United States was 1.7%. In 2000, the death rate had dropped to 0.9% (almost half). Children in 1900 were 10 times more likely to die than children in 2000. Several factors have reduced death rates:

1. Increased food and more efficient distribution that result in better nutrition
2. Improvements in medical and public health technology
3. Improvements in sanitation and personal hygiene
4. Safer water supplies

Human population has had three surges in growth. These surges in population have been attributed to three factors: The first was the use of tools and fire. The second was the agricultural revolution, when humans stopped being hunter-gatherers and began to raise crops. The third was the industrial and medical revolutions within the last 200 years. Birth rate or crude birth rate is equal to the number of live births per 1,000 members of the population in one year. Death rate or crude death rate is equal to the number of deaths per 1,000 members of the population in one year. Immigration refers to the number of individuals that enter the population, while emigration refers to the number of individuals that leave the population. Population change can be calculated from the following formula:

Population change = (crude birth rate + immigration) – (crude death rate + emigration)

EXAMPLE

In 1950, the population of a small suburb in Los Angeles, California, was 20,000. The birth rate was measured at 25 per 1,000 population per year, while the death rate was measured at 7 per 1,000 population per year. Immigration was measured at 600 per year, while emigration was measured at 200 per year. By how much did the population increase (or decrease) in that year?

Answer:

Population change = (crude birth rate + immigration) – (crude death rate + emigration)

= (25(20) + 600) – (7(20) + 200)

= +760

The population grew from 20,000 to 20,760 in one year.

The actual rate of population change can be determined by using the following formula:

$$\text{Actual growth rate (\%)} = \frac{\text{birth rate} - \text{death rate}}{10}$$

EXAMPLE

The United States had a birth rate of 14.6 live births per 1,000 population in one year, compared to India's birth rate of 22.2 in that same year. The death rate in that year for the United States was 8.3 deaths per 1,000 population, compared to India's rate of 6.4. Calculate the population growth rates (%) for both the United States and India for that year.

Answer:

$$\text{United States: } \frac{\text{birth rate} - \text{death rate}}{10} = \frac{14.6 - 8.3}{10} = 0.6$$

$$\text{India: } \frac{\text{birth rate} - \text{death rate}}{10} = \frac{22.2 - 6.4}{10} = 1.6$$

A current world growth rate of approximately 1.3% when applied to the about 6 billion people on Earth yields an annual increase of about 85 million people. Because of the large and increasing population size, the number of people added to the global population will remain high for several decades, even if growth rates decline.

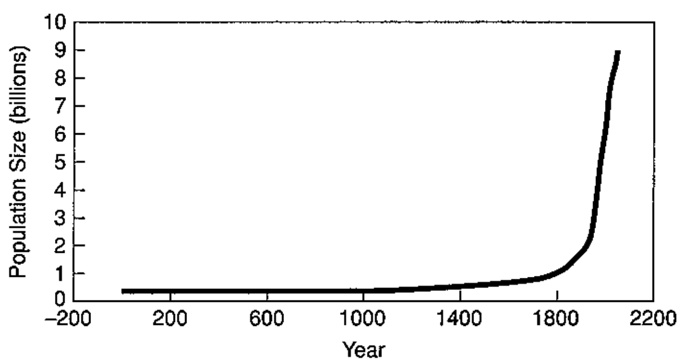


Figure 6.5 Estimated human population growth from 200 B.C.E. to 2200 C.E.

Distribution

In 1800, the vast majority of the world's population (65%) resided in Asia and Europe. By 1900, 25% of the human population lived in Europe largely due to the Industrial Revolution. Between 2000 and 2030, most of the growth will occur in the less-developed countries in Africa, Asia, and Latin America whose growth rates are much higher than those in more-developed countries. The more-developed countries in Europe and North America will have growth rates less than 1%. Some countries such as Russia, Germany, Italy, and Japan will even experience negative growth rates.

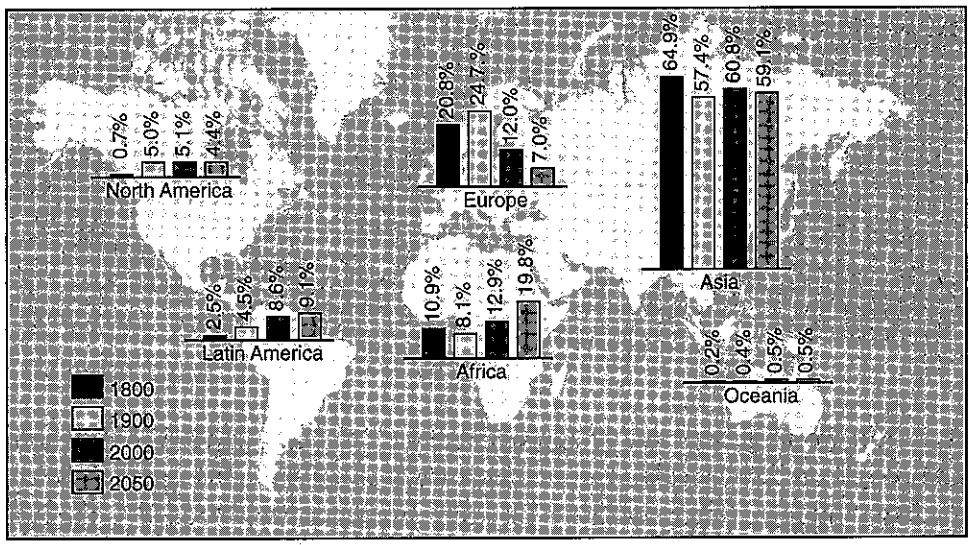


Figure 6.6 Human distribution patterns, 1800 C.E. to 2050 C.E.

(Source: United Nations Population Division, Briefing Packet, 1998 Revision of World Population Prospects)

Human Population Growth

Time Period	Description	Practicing Worldview
Before Agricultural Revolution	~ 1 million to 3 million humans. Hunter-gatherer lifestyle.	**Earth Wisdom**—Natural cycles that can serve as a model for human behavior.
8000 B.C.E. to 5000 B.C.E.	~ 50 million humans. Increases due to advances in agriculture, domestication of animals, and the end of a nomadic lifestyle.	
5000 B.C.E. to 1 B.C.E.	~ 200 million humans. Rate of population growth during this period was about 0.03 to 0.05%, compared with today's growth rate of 1.3%.	**Frontier Worldview**—Viewed undeveloped land as a hostile wilderness to be cleared and planted, then exploited for its resources as quickly as possible.
0 C.E. to 1300 C.E.	~ 500 million humans. Population rate increased during the Middle Ages because new habitats were discovered. Factors that reduced population growth rate during this time were famines, wars, and disease (density-dependent factors).	
1300 C.E. to 1650 C.E.	~ 600 million humans. Plagues reduced population growth rate. Up to 25% mortality rates are attributed to the plagues that reached their peak in the mid-1600s.	
1650 C.E. to present	Currently ~ 6 billion humans. In 1650 C.E. growth rate was ~ 0.1%. Today it is ~ 1.3%. Health care, health insurance, vaccines, medical cures, preventative care, advanced drugs and antibiotics, improvements in hygiene and sanitation, advances in agriculture and distribution, and education are factors that have increased the growth rate.	**Planetary Management**—Beliefs that as the planet's most important species, we are in charge of Earth; we will not run out of resources because of our ability to develop and find new ones; the potential for economic growth is essentially unlimited; and our success depends on how well we manage Earth's life-support systems mostly for our own benefit.
Present to 2050 C.E.	Estimates are as high as ~ 15 billion.	**Earth Wisdom**—Beliefs that nature exists for all Earth's species and we are not in charge of the Earth; resources are limited and should not be wasted. We should encourage Earth-sustaining forms of economic growth and discourage Earth-degrading forms of economic growth; and our success depends on learning how Earth sustains itself and integrating such lessons from nature into the ways we think and act.

Fertility Rates

Replacement level fertility (RLF) is the level of fertility at which a couple has only enough children to replace themselves, or about 2 children per couple. It takes a RLF of 2.1 to replace each generation since some children will die before they grow up to have their own two children. RLF rates are lower in moderately developed countries (MDC) and higher in less-developed countries (LDC) due to higher infant mortality rates in LDCs. Infant mortality rates are good indicators of comparative standards of living. The total fertility rate (TFR) is the average number of children that each woman will have during her lifetime. The country of Niger in Africa leads the world's TFR at 7.46.

Worldwide Total Fertility Rate

Country	TFR
Niger	7.46
India	2.73
Mexico	2.42
Israel	2.41
United States	2.09
China	1.73
European Union	1.47
Japan	1.40
Russia	1.28
Hong Kong	0.95
World average	**2.59**

Despite half of the world's population having subreplacement fertility rates, the world's population is still growing quickly. This growth is due to nations with above-replacement TFRs and a population momentum caused by large numbers of younger females who have as yet not had children.

Declines in fertility rates can be attributed to several factors. Urbanization results in a higher cost of living. Urbanization reduces the need for extra children to work on farms. There is a greater personal acceptance and government encouragement of contraception and abortion. The numbers of females in the workforce and female educational opportunities are increasing. More individuals desire to increase their standard of living by having less children. Many people are postponing marriage until their careers are established.

The two main effects of TFRs less than 2.1 without additions through immigration are population decline and population aging. In the United States the TFR has been inconsistent. The greatest TFR occurred during the post-World War II years (baby boomers). New immigrants and their descendants are projected to contribute 66% of the expected growth by 2050.

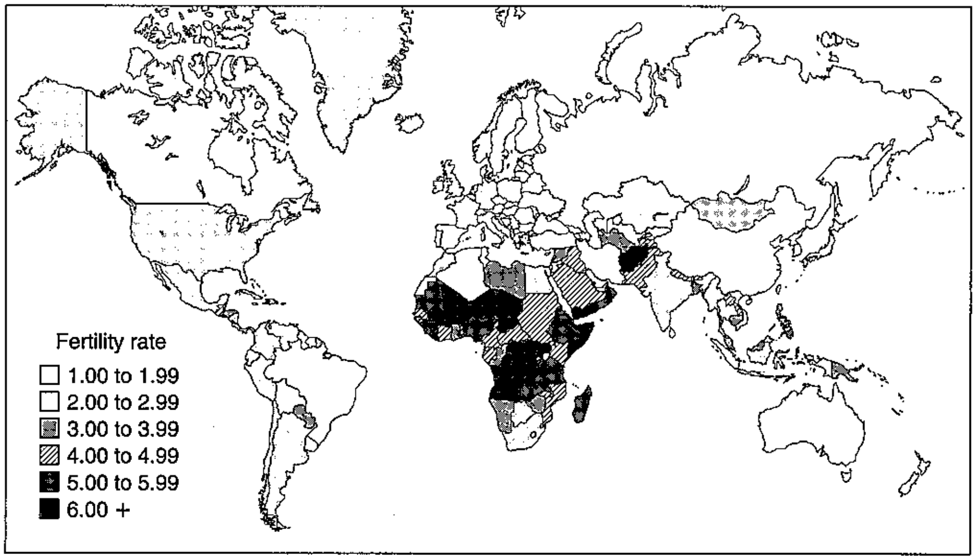


Figure 6.7 Worldwide total fertility rates

Growth Rates and Doubling Times

The 20th century saw the largest increase in the world's population in human history. The following chart shows the doubling times of the world's population:

950 C.E. to 1600	650 years
1600 to 1800	200 years
1800 to 1925	125 years
1925 to 1975	50 years
1975 to 2025	50 years

Note that the doubling times from 1925 to 1975 and projected from 1975 to 2025 remain constant. This does NOT mean that the world is not increasing in population—it means that the growth *rate* has decreased as shown in the following figure.

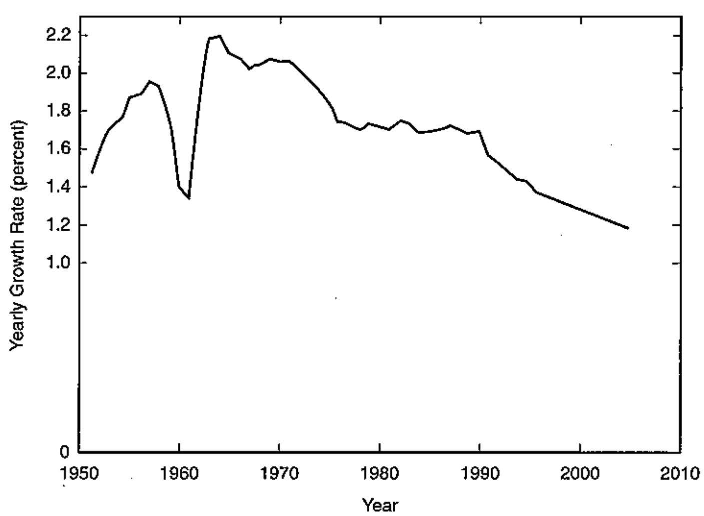


Figure 6.8 Yearly growth rate of human population (1950–2010)

Rule of 70

The Rule of 70 is a useful rule of thumb that roughly explains the time periods involved in exponential growth at a constant rate. To find the doubling time of a quantity growing at a given annual percentage rate, divide the percentage number into 70 to obtain the approximate number of years required to double. For example, at a 2% annual growth rate, doubling time is 70 / 2 = 35 years.

To find the annual growth rate, divide 70 by the doubling time. For example, 70 / 35 years doubling time = 2, or a 2% annual growth rate.

Demographic Transition

Demographic transition is the name given to the process that has occurred during the past century. It leads to a stabilization of population growth in the more highly developed countries and is generally characterized as having four separate stages: preindustrial, transitional, industrial, and postindustrial.

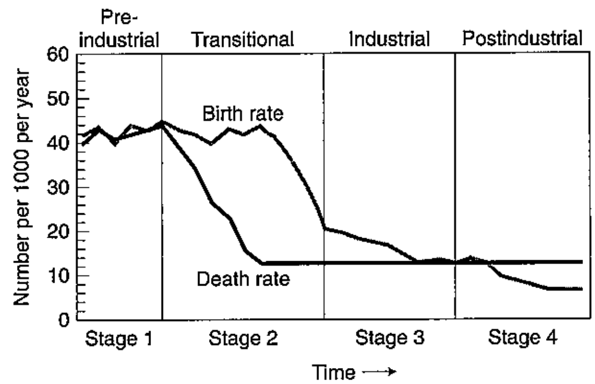


Figure 6.9 Demographic transitions occurring in human populations.

STAGE 1: PRE-INDUSTRIAL

Living conditions are severe, medical care is poor or nonexistent, and the food supply is limited due to poor agricultural techniques, preservation, and pestilence. Birth rates are high to replace individuals lost through high mortality rates. The net result is little population growth. Many countries in sub-Saharan Africa have reverted back to this stage due to the increase of AIDS.

STAGE 2: TRANSITIONAL

This stage occurs after the start of industrialization. Standards of hygiene, advances in medical care, improved sanitation, cleaner water supplies, vaccination, and higher levels of education begin to drive down the death rate, leading to a significant upward trend in population size. The net result is a rapid increase in population. Examples include India, Pakistan, and Mexico.

STAGE 3: INDUSTRIAL

Urbanization decreases the economic incentives for large families. The cost of supporting an urban family grows, and parents are more actively discouraged from having large families. Educational and work opportunities for women decrease birth rates. Obtaining food is not a major focus of the day. Leisure time is available.

Retirement safety nets are in place, reducing the need for extra children to support parents. In response to these economic pressures, the birth rate starts to drop, ultimately coming close to the death rate. An example is China.

STAGE 4: POST-INDUSTRIAL

Birth rates equal mortality rates, and zero population growth is achieved. Birth and death rates are both relatively low, and the standard of living is much higher than during the earlier periods. In some countries, birth rates may actually fall below mortality rates and result in net losses in population. Examples of declining populations include Russia, Japan, and many European countries. The developed world currently remains in this fourth stage of demographic transition.

Age-Structure Diagrams

A good indicator of future trends in population growth is furnished by age-structure diagrams. Age-structure diagrams are determined by birth rate, generation time, death rate, and sex ratios. The age-structure diagrams in the next figure show age distributions of less-developed countries compared with more developed countries for the year 2000 and projections for the year 2050. When the base is large (greater number of younger individuals in the population), there is a potential for an increase in the population as these younger individuals mature and have children of their own (population momentum). When the top of the pyramid is larger, it indicates a large segment of the population is past their reproductive years and indicates a future slowdown in population growth. Age-structure diagrams reflect demographic transitions.

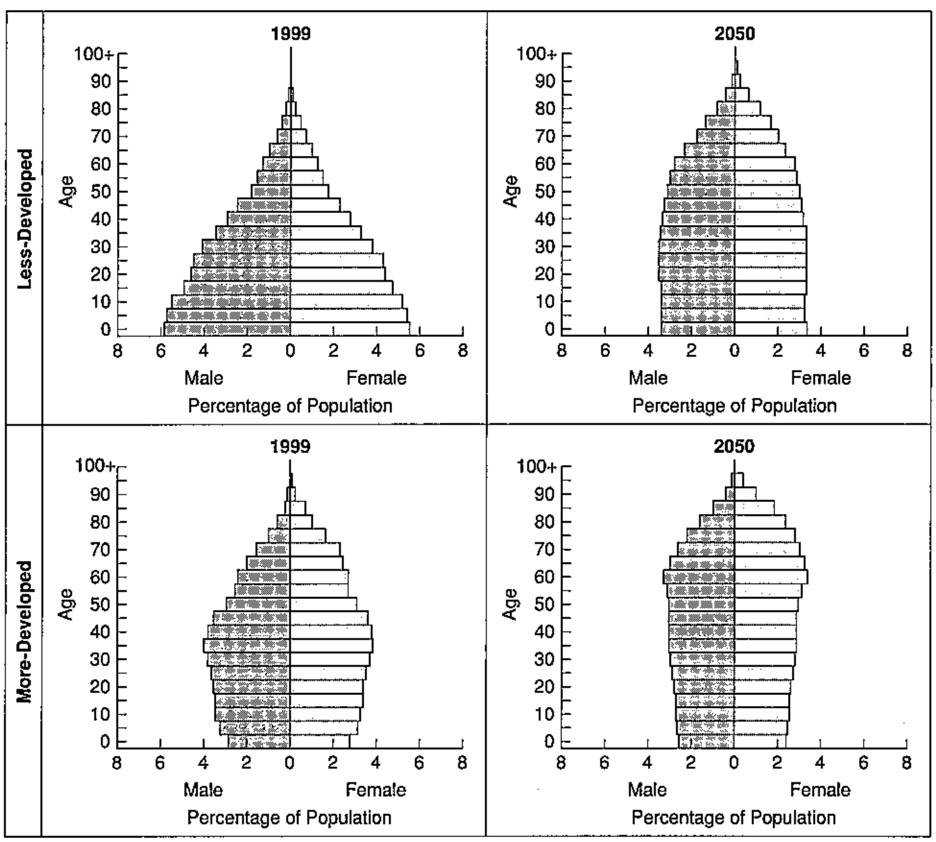
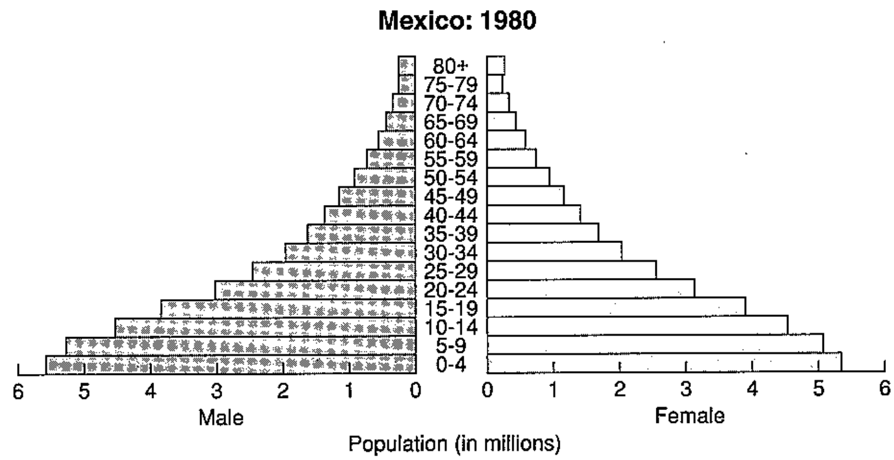
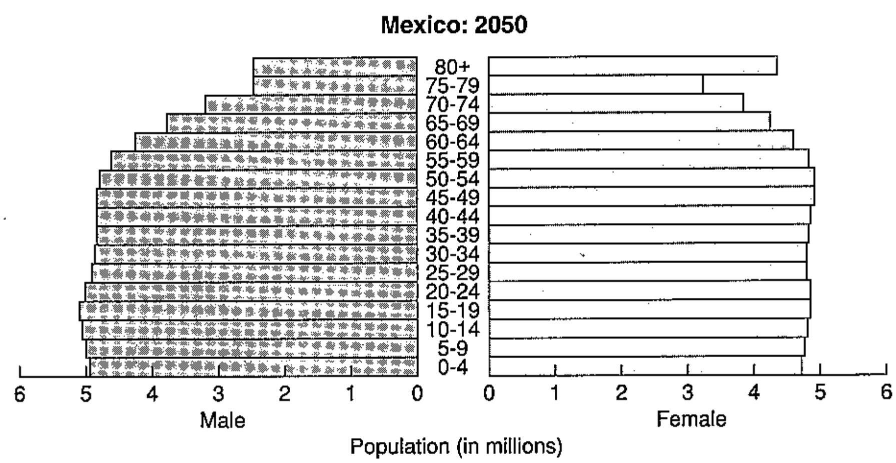


Figure 6.10 Age structure diagrams comparing less-developed countries to more-developed countries in the next 50 years. *(Source: United Nations)*

In Mexico, large family size is due to the necessity for farm labor, the need to support parents when they no longer work, a need to increase family income, and cultural and religious beliefs. The death rate has declined due to social and medical programs. However, the birth rate continues to remain high.



Source: U.S. Census Bureau, International Data Base.



Source: U.S. Census Bureau, International Data Base.

Figure 6.11 Age structure in Mexico, 1980 and 2050 (estimated)

POPULATION SIZE

This section discusses several strategies to sustain population size. It then provides a few case studies.

Strategies for Sustainability

- Provide economic incentives for having fewer children.
- Empower and educate women. The low status of women is the number one problem.
- Education usually leads to higher incomes. Higher incomes decrease the need for having extra children to take care of older parents.
- Higher education usually results in having children later in life.

- Provide government family planning services. These practices have ranged from education and birth control to sterilization and abortion.
- Improve prenatal and infant health care. Women would not need more children if the ones they had survived.
- Increase economic development in less-developed countries through free trade and private investment with tax incentives.

Case Studies and National Policies

Both China and India have instituted national policies to decrease their growing populations.

CHINA

Between 1972 and 2000, China dramatically reduced its crude birthrate by half (the TFR dropped from 5.7 to 1.8). The family planning program in China is one of the most efficient and strictest programs in the world. It includes a mobile program that reaches the rural population. Incentives such as extra food, larger pensions, better housing, free medical care, free school tuition, and salary bonuses for parents who limit their number of children are responsible for the success of this program. Couples are encouraged to postpone marriage and to have only one child. (If the first child is female, then the parents are allowed to have another child and still retain the financial incentives.) After a mother's first child is born, a woman is required to wear an intrauterine device. Removal of the device is a crime subject to sterilization. Physicians receive bonuses for sterilization procedures. Couples are punished for refusing to terminate unapproved pregnancies and for giving birth under the legal marriage age. Penalties include fines (up to 50% of their yearly salary), loss of land, less food, a decrease in farm supplies, loss of government benefits, and/or discharge from the Communist Party.

INDIA

In 1952, India (with a population of 400 million at the time) began its first family planning program. In 2000, India's population was 1 billion, or 16% of the world's population. Each day there are 50,000 live births in India. One-third of the population of India earns less than 40 cents per day, and cropland has decreased 50% per capita since 1960. In the 1970s, India instituted a mandatory sterilization program involving vasectomies. Some of the reasons for India's failures were poor planning, low status of women, favoring male children, and insensitivity to cultures and religion. Tubal ligation is the preferred method of family planning in India today. Condoms are free from the Indian government but have less than 10% use. Other birth control methods are usually accepted by only the upper/educated class.

IMPACTS OF POPULATION GROWTH

When left unchecked, population growth often results in hunger. Diseases and economics also affect population growth.

Hunger

A large portion of the world's population—25%—is malnourished. Areas of greatest malnutrition are Africa, Asia, and parts of Latin America. Consequently, these are areas with the highest TFRs. Several factors contribute to malnutrition.

1. Poverty
2. Droughts, which will only increase as the impact of global warming becomes more severe
3. Populations that have surpassed their carrying capacity
4. Political instability and wars, which cause mass migrations
5. Pestilence
6. Foreign investors who own large landholdings and whose sole motivation is profit (selling the food to the highest bidder, which often means exporting it)

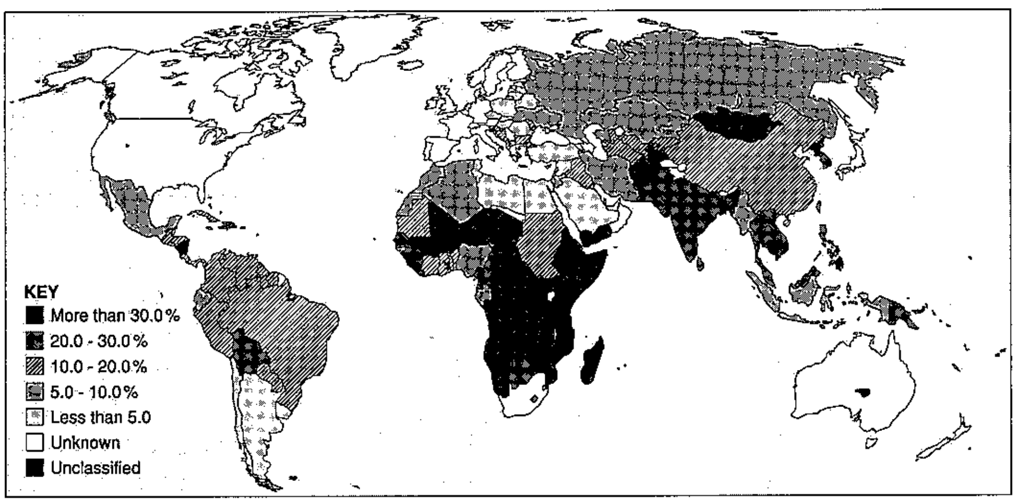


Figure 6.12 Worldwide malnutrition

Advances made during the first and second green revolutions (which focused on food production) are not ending world famine. In India, Mexico, and the Philippines, where large advances were made in crop production, famine is still common. Exports from these and other poor countries caused by distributors receiving higher profits from richer countries is actually making famine worse. Profit motives result in removing food from countries that grow it and sending the food to other countries that are able to pay higher prices.

Large-scale agribusiness or corporate ownership of farmland will not solve world hunger. Land reform in Japan, Zimbabwe, Taiwan, and Brazil has redistributed land into smaller holdings. It has also raised agricultural output an average of 80%.

The issue of malnutrition is not that the world does not produce enough food. The issue is that too many people cannot afford it or that it is not distributed efficiently. Enough wheat, rice, and grain are produced on Earth each day to provide each human with 3,500 calories per day (2,500 calories is the minimum daily requirement for men, and 2,000 calories is the minimum daily requirement for women). This does not even include vegetables, beans, nuts, meats, and fish processed each day. If all food grown and raised on Earth was distributed equally, it would result in 4.3 pounds (2 kg) per person per day.

Disease and Economic Impact

This section discusses how disease and economic realities affect population growth.

AIDS

In the United States, more than half a million people have died from complications arising from AIDS since 1981. An estimated 15,000 currently die annually according to the Federal Centers for Disease Control and Prevention. More than 1 million people in the United States are living with the virus, and 40,000 become infected each year. African-Americans, who make up approximately 13% of the U.S. population, account for half of new U.S. infections and a third of all AIDS-related deaths. African-American males are 7 times more likely as Caucasian males to be infected with HIV. African-American females are 20 times more likely to be infected as Caucasian females. The fastest growing population in the United States for new infections are 15 to 24 years old.

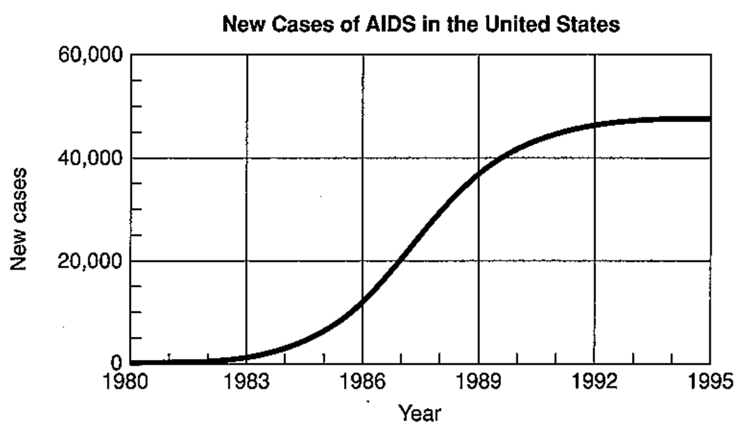


Figure 6.13 Growth curve for new cases of AIDS in the U.S. between 1980 and 1995. Notice how it follows the classic logistic growth model.

Worldwide, at least 25 million people have died from AIDS, and 2.8 million died in 2006, according to the World Health Organization. AIDS could kill 31 million people in India and 18 million in China by 2025, according to projections by U.N. population researchers. The toll from AIDS over the next 25 years will go far beyond the 34 million people thought to have died from the bubonic plague in the 14th century or the 20 to 40 million people who perished in the 1918 Spanish flu pandemic. AIDS is the leading cause of death in Africa, which has accounted for nearly half of all global AIDS deaths.

The epidemic is still growing. Its peak could be a decade or more away. In at least seven countries, the U.N. estimates that AIDS has reduced life expectancy to 40 years or less. Botswana has the highest HIV prevalence in the world; 36% of the country's 1.6 million people are HIV positive. AIDS experts predict that by 2010, more than 50% of Botswana's children will be AIDS orphans and the average life expectancy will have fallen from 47 years to 27 years.

PANDEMICS

The Spanish influenza pandemic of 1918 to 1919 killed somewhere between 20 and 40 million people worldwide, with 28% of all Americans infected. It has been cited as the most devastating pandemic in recorded world history. More people died of Spanish influenza in a single year than in the four years of the plague from 1347 to 1351. The flu was most deadly for people ages 20 to 40. This was unusual for influenza, which is normally a killer of the elderly and of young children.

According to the World Health Organization, if a mutant form of bird flu virus (H5N1) develops that could pass from person to person, it could kill as many as 7 million people worldwide and infect nearly one-third of the world's population. Infectious disease experts fear the virus may mutate within a pig that harbors both human and avian forms of the flu virus.

OTHER DISEASES

The World Health Organization estimates that by 2020, tobacco-related illnesses, including heart disease, cancer, and respiratory disorders, will be the world's leading killer. They will be responsible for more deaths than AIDS, tuberculosis, road accidents, murder, and suicide combined. In 2005, estimated losses in national income from heart disease, strokes, and diabetes was $18 billion in China, $11 billion in the Russian Federation, and $9 billion in India.

Tuberculosis is the leading cause of death in many poorer countries. Its economic impact on global economies is estimated to be $12 billion.

Each year, approximately 500 million malaria infections lead to over 1 million deaths, 75% of which occur among children living in Africa. Mortality rates due to malaria are rising among young children, and drug therapies that were once fairly effective in treating malaria are becoming less effective as newer strains become more drug-resistant.

Resource Use and Habitat Destruction

Three methods are used to estimate the effects of humans on patterns of resource utilization: measure net primary productivity, estimate how much impact humans have had on Earth, and examine finite resources and from that draw conclusions on increasing productivity. Net primary productivity (NPP) is the total amount of solar energy converted into biochemical energy through photosynthesis minus the energy needed by those plants for their own metabolic requirements. It is a quantifiable measure of resources available on Earth. The NPP without human activity has been estimated to be 150 billion tons of organic matter per year. Human activity has caused a 12% decline in the NPP due to deforestation. Humans utilize about 27% of the NPP for their own purposes (food, building material, energy, and so on) or by converting productive land to nonproductive purposes. When added up, humans utilize about 40% of the NPP and leave all other life on Earth with 60%. The difference grows with the ever-increasing human population growth.

Of the NPP of the oceans, about 8% is utilized for human purposes. In nutrient-rich upwelling areas, humans utilize about 25%. In temperate continental shelf waters, humans utilize approximately 35% of the NPP.

If humans utilized 100% of the NPP (leaving nothing for all other life-forms on Earth), the theoretical maximum sustainable human population at 100% of the carrying capacity would be 15 billion people—which could be achieved during the 21st century. In this scenario, every square centimeter of Earth would be utilized for human needs. The following table lists factors that affect resource utilization.

Factors That Affect Resource Utilization

Factor	Description
Carrying capacity	See the section "Carrying Capacity (*K*)" in this chapter.
Energy resources	One average American consumes as much energy as 500 Ethiopians or 35 people from India.
Environmental degradation	Due to increased population size, erosion, desertification, pollution, impact on the ozone layer, and gases that contribute to global warming all increase.
Exploitation of natural resources as a function of gross domestic product	The richest 20% of the world's population contribute to resource depletion of energy and raw materials through overconsumption. This in turn, leads to disproportionate amounts of pollution. The poorest 20% of the world's population are forced to deplete resources by being forced to cut down forests, clear land, and farm marginal land.
Extinction of animal and plant species	Close to 50% of all species of animals and plants on Earth could be on a path toward extinction within 100 years. 11% of all bird species and 13% of all plant species are at risk for extinction.
Famine	See the section "Hunger" in this chapter.
Political unrest	Affects employment, food distribution and standard of living that, in turn, affect utilization of resources.
Population density	Density, more than population size, has a greater effect on the amount of pollution and use of energy.
Population size	Large numbers of people lead to high rates of habitat loss and natural resource depletion.
Poverty	20% of the world's richest countries control 80% of the world's wealth. The poorest 20% of the world's population controls just 1.5% of the world's economic resources.
Technological development	More-developed countries consume more resources than less-developed countries. The United States represents about 5% of the world's population but consumes 25% of the world's resources and generates 25% of the world's waste.

CASE STUDY

Conference on Population and Development, Cairo (1994): The plan calls for improved healthcare and family planning services for women, children, and families throughout the world. It also emphasizes the importance of education for girls as a factor in the shift to smaller families.

TIP

Do NOT start preparing for the APES exam a few weeks ahead of time. The APES exam is actually one of the toughest AP Exams given. In 2006, half of all students taking the exam received a 1 or 2. Pace yourself and be sure to get lots of rest before the exam day. Don't just read the practice essays in this book—write them out.

QUICK REVIEW CHECKLIST

- ☐ **Population Biology Concepts**
  - ☐ population ecology
  - ☐ factors that affect population viability
  - ☐ carrying capacity
  - ☐ J-curves
  - ☐ S-curves
  - ☐ reproductive strategies
    - ☐ *r*-strategists
    - ☐ *K*-strategists
  - ☐ survivorship
    - ☐ survivorship curves
      - ☐ Type I
      - ☐ Type II
      - ☐ Type III
- ☐ **Human Population Dynamics**
  - ☐ historical population sizes
  - ☐ calculating population change
    - ☐ crude birth rate
    - ☐ crude death rate
    - ☐ immigration
    - ☐ emigration
  - ☐ distribution
- ☐ **Fertility Rates**
  - ☐ replacement fertility rate (RLF)
  - ☐ total fertility rate
  - ☐ growth rates
  - ☐ doubling time
- ☐ **Demographic Transition**
  - ☐ stage 1
  - ☐ stage 2
  - ☐ stage 3
  - ☐ stage 4
- ☐ **Age Structure Diagrams**