3 Managing Our Population and Consumption

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Learning Outcomes

After reading this chapter, you should be able to

- Explain how and why the human population has changed over time.
- Define determinants of population change.
- Interpret an age-structure pyramid.
- Deconstruct how the demographic transition model explains population growth over time.
- Analyze the effectiveness of direct and indirect efforts to control population growth.
- Compare and contrast China's and Thailand's population policy.
- Describe how population size, affluence, and technology interact to impact the environment.

At 2 minutes before midnight on Sunday, October 30, 2011, a 5.5-pound baby girl named Danica May Camacho was born in a government-run hospital in Manila, Philippines. Danica May was just one of thousands of babies born in the Philippines that day and just one of hundreds of thousands born around the world each day. Yet Danica May's birth represented a milestone for reasons that her parents could never have imagined. The United Nations Population Division decided to symbolically designate Danica May as the world's 7 billionth person and to declare October 31, 2011, as the Day of Seven Billion to call attention to the issue of world population growth. Danica May was greeted with a burst of camera flashes, applause from hospital staff and United Nations officials, and a chocolate cake with the words "7B Philippines" on it. Her stunned parents also received gifts and a scholarship grant for her future education.

Was Danica May Camacho actually the world's 7 billionth person? We will likely never know. For the United Nations, determining the exact date and precise birth location of the world's 7 billionth person was beside the point. The fact remains that about 250 babies are born somewhere in the world every minute. This translates to 360,000 births every day and over 130 million new people on the planet every year. Because humans are dying at less than half that rate—104 deaths per minute, 150 thousand per day, and 55 million per year—global population is currently growing at a rate of roughly 75 million per year. In other words, we are adding the equivalent of a new Germany or Vietnam to the global population each year. Since Danica May symbolized the 7 billionth person in late 2011, the global population has continued to grow to over 7.7 billion. Over 700 million more people have joined the human family in time for Danica May's seventh birthday.

Whether global population will continue to grow at this rate, slow, or even decline in the decades ahead has enormous implications for the environment. The number of people on the planet, combined with the resource and material consumption patterns of those people, are key drivers of environmental change and an important subject in the study of environmental science. This chapter will first review how human population has changed over time, increasing gradually over tens of thousands of years before going from 1 billion to over 7 billion in just the past 200 years. We'll then examine human population growth using the science of demography, the study of population changes and trends over time. Demography will help us better understand how and why population has changed, and it also allows us to examine what might happen to population in the future. This will be followed by a discussion of population policy and fertility control, utilizing case studies of countries around the world that have responded in different ways to changing population patterns. Finally, we will consider how population growth, combined with resource and material consumption patterns, affects the natural environment. We'll see that absolute numbers of people in a given population are just one factor in determining the impact that population will have on the environment.

3.1 Population Change Through Time

Recall from Chapters 1 and 2 that many environmental scientists describe the period we live in as the Anthropocene, or the age of humans. Human activities are now the dominant influence on the environment, the oceans, the climate, and other Earth systems. We have converted large areas of the planet's surface to cities, suburbs, farms, and other forms of development.

The waste products of our modern industrial society, including radioactive and other long-lived wastes, can be detected in even some of the most remote locations of the globe. Our activities are fundamentally altering the chemical composition of the world's atmosphere, oceans, and soils. And we are now driving other species to extinction at rates that are 100 to 1,000 times greater than "normal" or background rates of extinction.

It may come as some surprise then to consider that for much of human history our very survival as a species was in question. We can divide human history into three broad periods: the preagricultural, the agricultural, and the industrial.

Preagricultural Period

The **preagricultural period** of human history dated from over 100,000 years ago to about 10,000 years ago. During this time, humans developed primitive cultures, tools, and skills and slowly migrated out of Africa to settle Europe, Asia, Australia, and the Americas. Disease, conflict, food insecurity, and environmental conditions kept human numbers low, perhaps as low as 50,000 to 100,000 *across the entire planet*. That's about the same as today's population of a small city in the United States, such as Albany, New York; Trenton, New Jersey; Roanoke, Virginia; or Tuscaloosa, Alabama. By the end of the preagricultural period about 10,000 years ago, the human population across the globe had risen to roughly 5 million to 10 million, about the same as New York City today.

Agricultural Period

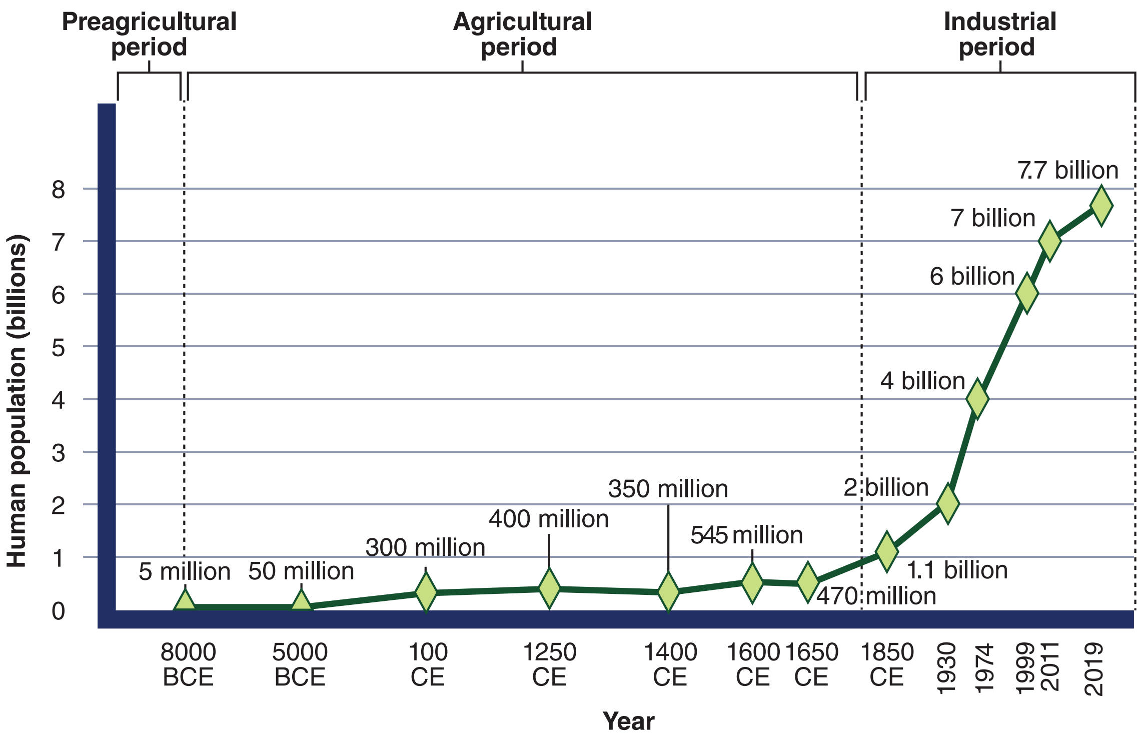
The **agricultural period** of human history, starting about 10,000 years ago, set the stage for more rapid growth in human numbers. The domestication of plants and animals, selective breeding of nutrient-rich crops, and the development of technologies like irrigation and the plow greatly increased the quantity and security of food supplies for the human population. By the year 5000 BCE (7,000 years ago), there were perhaps 50 million people on the planet. By 2,000 years ago, that number may have risen to 300 million, about the same as the population of the United States today. Despite the advances brought on by the agricultural revolution, population growth remained low due to warfare, disease, and famine. For example, between 1350 and 1650, a series of bubonic plagues known as the Black Death ravaged much of Europe, killing as much as one third of the continent's population. High birth rates helped offset high mortality rates, and by the end of the agricultural period 200 years ago, global population stood at close to 1 billion (Kaneda & Haub, 2018).

Industrial Period

The introduction of automatic machinery around the middle of the 18th century ushered in the **industrial period**, the period we are still in today. A combination of factors has caused dramatic increases in the human population during this time. The Industrial Revolution led to sharp increases in food production. Advances in science resulted in improved medicines and medical care. Better understanding of communicable diseases prompted improvements in sanitation and water quality. All of these developments helped extend life expectancy, reduce mortality rates, and decrease infant mortality. However, because birth rates did not drop at the same time, human population began to grow more dramatically (see Figure 3.1). While it took all of human history—over 100,000 years—to reach a global population of 1 billion around the year 1800, it took only about 120 years to double that number to 2 billion in 1927. Thirty-three years later, in 1960, world population reached 3 billion. Since 1960 another billion people have been added to the population every 12 to 14 years—1974, 1987, 1999, and 2011 (Population Reference Bureau, 2018).

Figure 3.1: Human population growth

The human population began to increase dramatically starting in the industrial period.



*Based on data from "2018 World Population Data Sheet," by Population Reference Bureau, 2018 (**https://www.prb.org/wp-content/uploads/2018/08/2018_WPDS.pdf**).*

Predicting when the 8, 9, or 10 billionth person will be added to the world's population depends on assumptions about human fertility and health trends. The decisions that young people make today about when and if to marry, whether to use contraception and family planning, and how many children to have will influence future changes to the population. The United Nations Population Division (2017) now projects that world population will grow to 8.6 billion by 2030, 9.8 billion by 2050, and 11.2 billion by 2100. Whether we hit the 11.2 billion mark in 2100, far surpass it, or never actually reach it at all will depend in large part on decisions made by what is known as the "largest generation." As of 2018, well over 40% of the world's population was younger than 25 years old, and nearly 2 billion people were under age 15 (United Nations Population Division, 2017). How the decisions made by these young people will affect future global population is the focus of Section 3.2.

3.2 Demographics

The science of **demography** focuses on the statistical study of human population change. The word *demography* is derived from the Greek words *demos* ("people") and *graphy* ("field of study"). A *demographer* is a person who studies demography, and demographers focus their research on *demographic* trends and statistics. As complex as the study of human populations may seem, it really boils down to understanding a handful of variables and measures that together determine changes in human numbers.

Birth and Death

The most basic determinants of a change in any given population are birth rates and death rates. Demographers measure births and deaths in a very specific way, using what they call crude birth rates and crude death rates. The **crude birth rate (CBR)** is the number of live births per 1,000 people in a given population over the course of 1 year. Likewise, the **crude death rate (CDR)** is the number of deaths per 1,000 people in a given population over the course of 1 year.

The best way to illustrate how CBR and CDR interact to determine population change is through a simple example. Imagine a small village or town cut off from the outside world. At the start of the year, there were 1,000 people in this village, but over the next 12 months, 20 children were born and 8 people died. How do these numbers translate into CBR and CDR? What does this mean for the overall population and rate of population growth? In this case, the CBR would be 20 and the CDR would be 8. The rate of population growth, what demographers call the **rate of natural increase**—birth rates minus death rates, excluding immigration and emigration—would be CBR – CDR, or 20 – 8 = 12, or 1.2% of the population of 1,000, leaving the population of the village at the end of the year to be 1,012.

Migration

In reality, towns and villages are typically not cut off from the outside world, so demographers also consider immigration and emigration as factors in population change. **Immigration** is people moving into a given population, while **emigration** is people moving out of that population. As with the rate of natural increase, demographers determine the **net migration rate** as the difference between immigration and emigration per 1,000 people in a given population over the course of 1 year.

Karen Kasmauski /SuperStock

When calculating population change, immigration and emigration must also be considered.

Fertility

Another important statistic that demographers focus on is the **total fertility rate (TFR)**. The TFR is the *average number* of children an individual woman will have during her childbearing years (currently considered to range from age 15 to 49). In preindustrial societies, fertility rates were often as high as 6 or 7. This was due to a number of factors. Since most were engaged in labor-intensive agriculture, large families were considered an asset. Because so many children died in infancy or childhood, women tended to have more children to ensure that at least some would survive. Earlier age at marriage, lack of contraception, and cultural factors also played a role in high fertility rates. Yet human populations grew slowly or not at all in preindustrial societies because death rates were also high.

It may seem like fertility rates (TFR) and birth rates (CBR) are measuring the same thing, but that's not the case. Recall that CBR is the number of births per 1,000 people in a given population over 1 year. TFR is the average number of children an individual woman will have during her childbearing years. A given population could be characterized by a high TFR and a low CBR if there were very few women of childbearing age. Likewise, there could be a low TFR and a high CBR if a large percentage of the population were women of childbearing age.

Age-Structure Pyramids

The link between fertility rates, the age structure of a population, and overall birth rates has led demographers to develop a visual tool they call an **age-structure pyramid**. Age-structure pyramids, also called population pyramids, are a simple way to illustrate graphically how a specific population is broken down by age and gender. Each rectangular box in an age-structure pyramid diagram represents the number of males or females in a specific age class—the wider the box is, the more people there are.

Age-structure pyramid diagrams for Uganda, the United States, and Japan are shown in Figure 3.2. Demographic data on CBR, CDR, TFR, immigration, and emigration for these countries are listed in Table 3.1. Demographers looking at these three age-structure pyramids could tell you immediately that Uganda is experiencing high rates of population growth, the United States is growing slowly or is stable, and Japan's population is in decline. How do they know this?

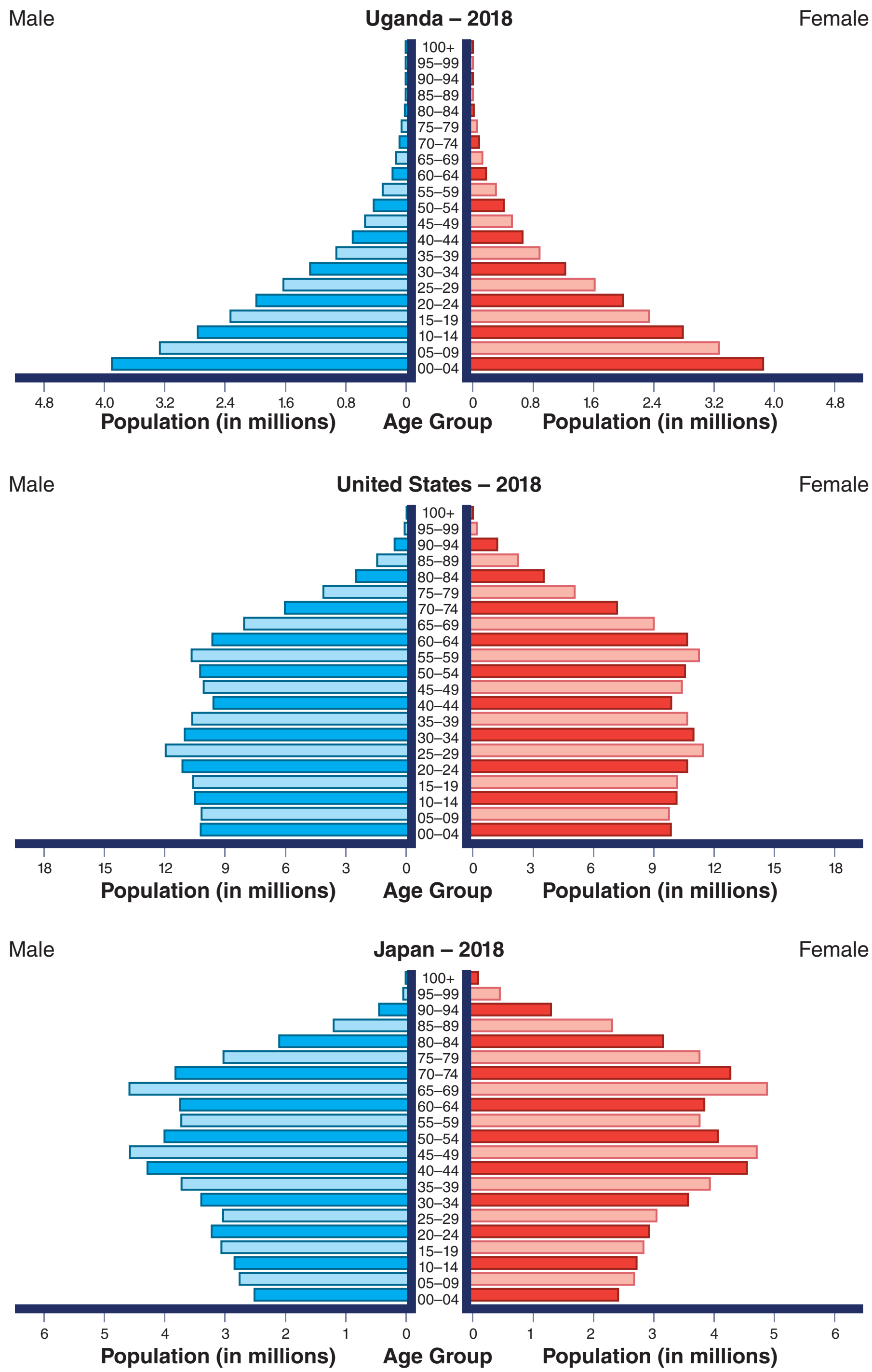
Table 3.1: Demographic data for Uganda, the United States, and Japan

Country	CBR (per 1,000)	CDR (per 1,000)	TFR	Net migration rate (per 1,000)	Rate of natural increase (percentage)
World	19	7	2.4	N/A	1.2
Uganda	41	9	5.4	–1	3.2
United States	12	9	1.8	3	0.3
Japan	8	11	1.4	1	–0.3

Source: "2018 World Population Data Sheet," by Population Reference Bureau, 2018 (https://www.prb.org/wp-content/uploads/2018/08/2018_WPDS.pdf).

Figure 3.2: Age-structure pyramids for Uganda, the United States, and Japan

The age-structure pyramids for these three countries can tell us what to expect of each country's population growth.



*Data from "International Data Base," by US Census Bureau, 2018 (**https://www.census.gov/data-tools/demo/idb/informationGateway.php**).*

Uganda

In the case of Uganda, the large numbers of people in the age classes for 0–4, 5–9, and 10–14 years suggest that the fertility rate and birth rate must be high, and the data in Table 3.1 confirms this. When the TFR is much higher than 2, it means that women in that population are having more children than are needed to "replace" the parents and maintain a certain population. This is why demographers typically refer to 2 as the **replacement rate**. Uganda's fertility rate of 5.4 means that, on average, each woman of childbearing age in that country is giving birth to more than 5 children over her lifetime. And because this number is far higher than the replacement rate of 2, Uganda's population is growing at an annual rate of 3.2%.

Even if fertility rates in Uganda were to be immediately reduced to around 2, the population would continue to grow for a few more decades because there are so many female children below age 15. This large number of young girls who have yet to enter their childbearing years creates built-in momentum for population growth, which demographers refer to as **demographic momentum**.

United States

The situation in the United States looks quite different than that of Uganda. Instead of being wide at the bottom, the age-structure pyramid for the United States is fairly even for ages between 0 and 70 or 75. This suggests that fertility rates in the United States must be close to the replacement rate and that birth rates and death rates are roughly similar to each other. The data in Table 3.1 confirms this. The fertility rate in the United States of 1.8 even suggests that the United States is below the replacement rate. If fertility rates in the United States remain at current levels, and if net migration stays the same or declines, the population growth rate in the United States will approach zero and possibly even turn negative in the years ahead.

Japan

On the complete opposite end of the spectrum from Uganda is Japan. Japan's age-structure pyramid actually gets wider at the middle and upper portions, suggesting that fertility rates are well below replacement levels and that overall population is stable or declining. Table 3.1 confirms this. The TFR in Japan is currently 1.4, and the CBR of 8 is lower than the CDR of 11. Overall, Japan's population is currently declining at a rate of –0.3% annually, with moderate levels of positive net migration helping slow the rate of population decline.

Learn More: Visualizing Population Growth

After reviewing all of the demographic terms and concepts, it might seem challenging to try to put them together and get a picture of how human populations change over time. This very simple video developed by National Public Radio at the time when world population hit 7 billion does a very good job of helping show how populations can change over time in response to just a handful of changing demographic factors—namely birth rates and death rates. See if the concepts presented help reinforce the material you just finished reading.

https://www.npr.org/2011/10/31/141816460/visualizing-how-a-population-grows-to-7-billion

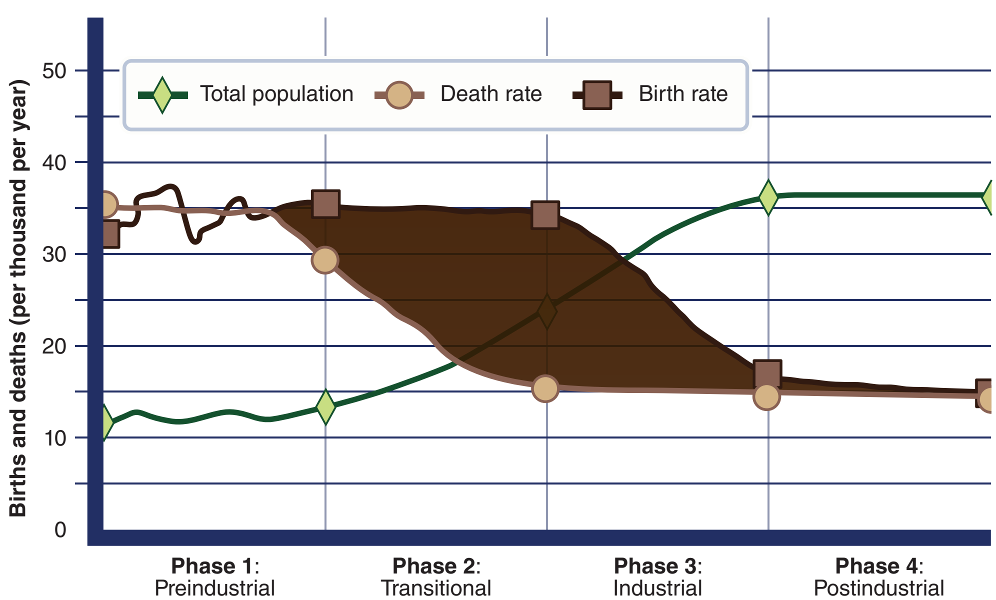
3.3 The Demographic Transition

For most of human history, both birth rates and death rates were relatively high, resulting in slow population growth. It was not until the time of the Industrial Revolution that this rough balance between birth and death rates begin to shift dramatically. Life expectancies increased and infant mortality and overall death rates declined—but birth rates generally remained high. In other words, the sudden increase in global population from 1 billion to over 7 billion in just 200 years was not because people started having more children, but because of a divergence or widening gap between birth rates and death rates as fewer people died. At first, most of this population increase was concentrated in the more industrialized, developed countries, where advances in food supply, medicine, and sanitation were more widespread. By the second half of the 20th century, this population growth began occurring in developing countries as these advances became available there as well.

Demographers use a model called the **demographic transition** to explain and understand the relationship between changing birth rates, death rates, and total population (see Figure 3.3). Phase 1 of the demographic transition model shows how human populations in preindustrial societies were generally characterized by high birth and death rates. These tended to cancel out one another and resulted in a fairly stable population. In Phase 2, as death rates begin to decline and birth rates remain high, the population increases. In Phase 3, as populations become more urbanized and as expectations of high infant mortality decline, birth rates also begin to drop. However, birth rates still exceed death rates, resulting in a continued natural increase in the population. Not until Phase 4 of the demographic transition do birth rates and death rates begin to converge again, and overall population begins to show signs of stabilizing.

Figure 3.3: The demographic transition

The four stages of demographic transition show the change in population growth that a country experiences over time as it develops and industrializes.



Contributing Factors

It's instructive to review some of the main factors that trigger changes in birth and death rates and move countries through various stages of the demographic transition.

A population's death rate will generally begin to drop when three things happen.

1. The food supply increases and becomes more stable.
2. Sanitation practices, such as sewage treatment, improve.
3. Advances in medicine, such as the development and use of antibiotics, occur.

All these factors were prevalent in developed countries during the latter part of the 19th century and into the 20th century, and death rates declined accordingly. For example, death rates in the United States were roughly 29.3 for every 1,000 people in 1850, and the average life expectancy at birth at that time was only about 40. By 1900 death rates had dropped to 17.2, and life expectancy at birth had increased to about 50. After U.S. death rates spiked to almost 20 during a global influenza outbreak in 1918, they continued to drop to 8.4 by 1950, roughly where they remain to this day, along with an average life expectancy of 78.7 (Arias, Xu, & Kochanek, 2019).

While we might expect birth rates to drop at roughly the same rate and at the same time as death rates, birth rates often remain high due to cultural factors, a desire for large families in rural households, and expectations of high infant mortality. Over time, however, cultural attitudes toward family size can change. Likewise, the need for a large family decreases as a population urbanizes and fewer people are engaged in labor-intensive agriculture. Finally, infant and child mortality rates fall as sanitation and medical care improve.

Developed Countries Versus Developing Countries

The United States and other developed countries were well into Phase 2 or 3 of the demographic transition by the start of the 20th century. Today these countries are in Phase 4, with very low fertility rates, low birth rates, and low death rates. In contrast, many developing countries were still in Phase 1 or 2 of the demographic transition as late as 1950. These countries had not seen the advances in medicine, food supply, clean water, and sanitation that the developed countries had achieved. In addition, many developing countries were still largely rural and dependent on agriculture, a situation that tends to promote high fertility and large family size. As a result, developing countries were characterized by high birth and death rates. From roughly 1950 onward, however, developing countries began to enter Phases 2 and 3 of the demographic transition, and their populations increased rapidly as a result. Today some developing countries, especially in Asia, are approaching or have already reached Phase 4 of the demographic transition. Meanwhile, others—especially in sub-Saharan Africa—could still be categorized as being in Phase 2 or 3.

Table 3.2 provides comparative demographic data for the world as a whole and for seven countries in different stages of the demographic transition. The West African country of Mali can still be said to be in Phase 2 of the demographic transition. Fertility and birth rates are still high, but improved access to medicine, sanitation, and food has dropped death rates to almost the world average. As a result, Mali's population is growing at a rapid rate of 3.5% and will double every 20 years if the growth rate remains the same. Senegal, also in West Africa, and Egypt in North Africa are moving from Phase 2 to Phase 3 of the demographic transition as fertility rates and birth rates have begun to decline in recent years. India is now solidly in Phase 3 of the demographic transition, since fertility rates have dropped to 2.3 and birth rates to 20 per 1,000. However, because India has a relatively young population—the age-structure pyramid is wider at the bottom—there is some built-in demographic momentum. As a result, India, already the second most populous country in the world after China, will become the most populous around the year 2022. The Southeast Asian nation of Malaysia is further along in the demographic transition than India. Meanwhile, countries like Denmark and South Korea are clearly already in Phase 4, a situation characterized by low fertility, low birth and death rates, and stable or even declining populations.

Table 3.2: Demographic data for countries in different phases

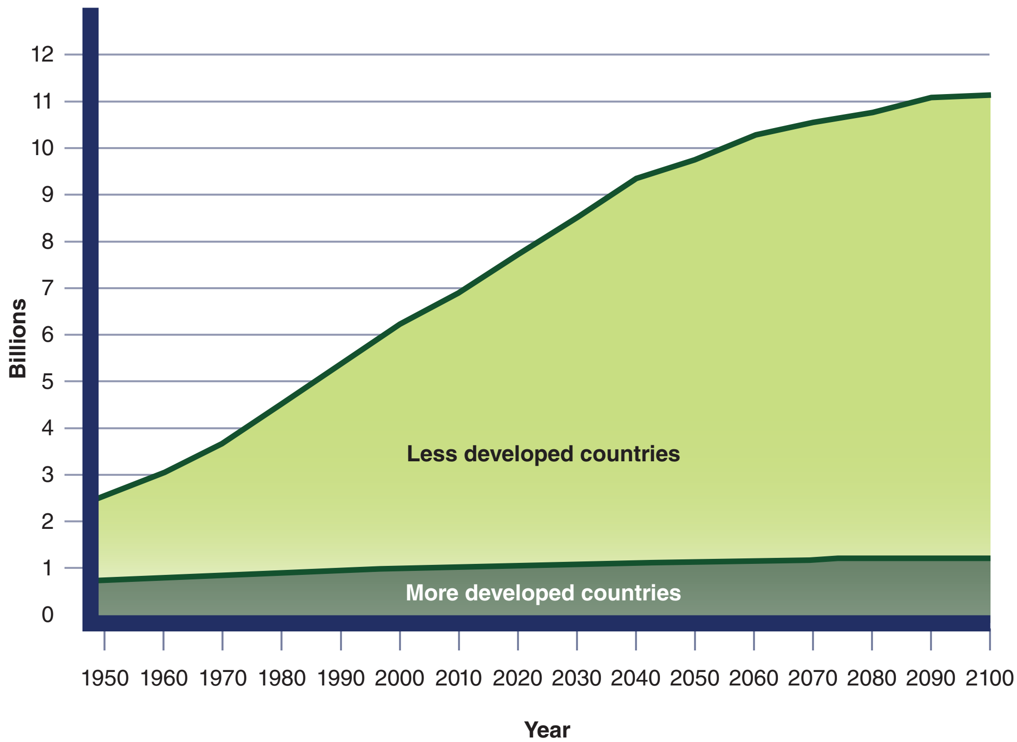
Country	CBR	CDR	TFR	Rate of natural increase	Demographic transition phase
World	19	7	2.4	1.2	3/4
Mali	45	10	6.0	3.5	2
Senegal	33	6	4.6	2.7	2/3
Egypt	27	6	3.4	2.1	2/3
India	20	6	2.3	1.4	3
Malaysia	16	5	1.9	1.1	3/4
Denmark	11	9	1.8	0.2	4
South Korea	7	6	1.1	0.1	4

Sources: "2018 World Population Data Sheet," by Population Reference Bureau, 2018 (https://www.prb.org/wp-content/uploads/2018/08/2018_WPDS.pdf); "International Data Base," by US Census Bureau, 2018 (https://www.census.gov/data-tools/demo/idb/informationGateway.php).

Because virtually all developed countries are in Phase 4 of the demographic transition, and because most developing countries are still in Phases 2 or 3, demographers predict with confidence that virtually all the world's population growth in the decades ahead will be in developing countries (see Figure 3.4). Close to 60% of that global increase in population will take place in Africa, with smaller increases in Asia and the Americas. Europe's population is projected to decline by about 16 million—not surprising, given the low fertility rates in most European countries. These are all projections, however. How much population growth will actually occur, and how fast we reach 8, 9, or 10 billion, will depend on how quickly developing countries move through the demographic transition. The speed of a country's demographic transition will ultimately depend on the decisions made by young people in those countries. Section 3.4 will cover the role of population policy in affecting those decisions and "speeding up" the demographic transition.

Figure 3.4: World population, 1950–2100

Demographers expect much of the world's population growth to come from developing countries, as the population in more developed countries stabilizes or even declines.



Data from "World Population Prospects: The 2017 Revision," DVD edition, by United Nations, Department of Economic and Social Affairs, Population Division, 2017 (https://population.un.org/wpp/Download/Standard/Population).

3.4 Population Policy and Fertility Control

As recently as the 1950s, an average woman anywhere on the planet gave birth to almost 6 children during her childbearing years. That global average has now declined to 2.4, with average fertility rates ranging from 1.6 in developed countries to 2.7 in developing countries. The United Nations predicts that average global fertility rates will continue to decline toward a replacement rate of 2 in the decades ahead and that, as a result, world population could stabilize by the end of this century at around 11 billion.

However, slight changes in fertility rates can have a profound impact on demographic trends. An increase in average fertility of just 0.5 children per woman could lead to a global population of over 15 billion by 2100. Likewise, a decrease in average fertility of 0.5 would result in a global population of 6.2 billion by 2100, over 1 billion less than today. Any effort to influence fertility rates, whether direct or indirect, can have a significant impact on future population trends. Efforts to control and influence population change usually invite controversy since they affect highly individual and personal behavior. Population policy is also often subject to scrutiny and criticism on religious and moral grounds. This section reviews the major factors that appear to influence fertility rates and the policy efforts to change them.

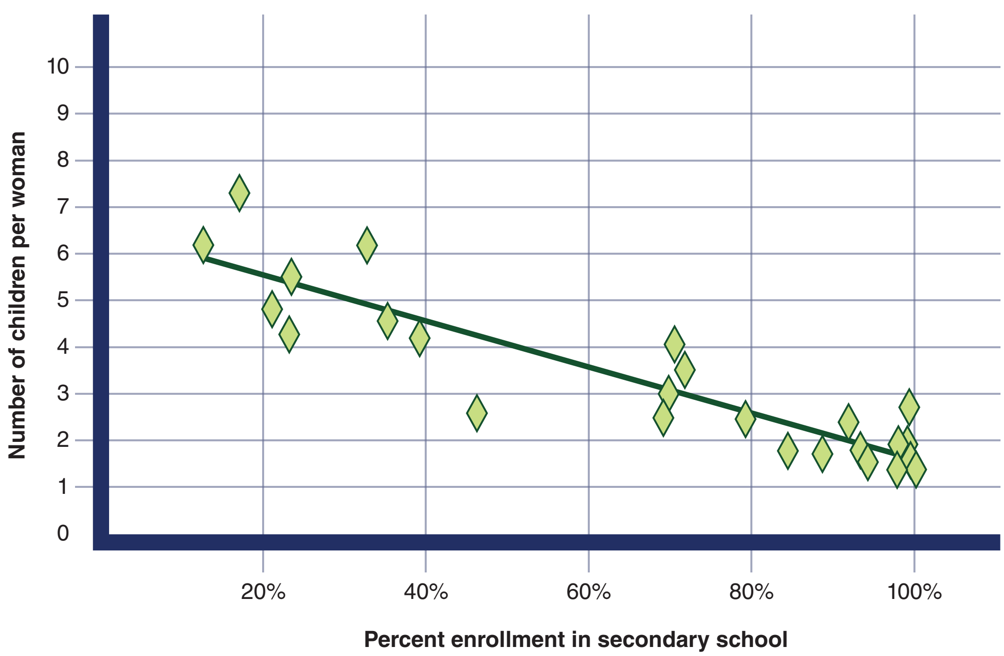
Direct Versus Indirect Factors

Broadly speaking, factors that influence fertility are either direct or indirect. *Direct factors* are those that have an immediate and tangible impact on a woman's decision or ability to have children. These mainly include the availability and affordability of contraception and family planning services. In some countries, such as China, contraceptive availability has also been linked with government incentives (and disincentives) to encourage couples to have fewer children (see the case study in Section 3.5). The availability of family planning services, combined with incentives to have fewer children, has led to dramatic reductions in fertility rates in China, from roughly 5 children per woman in the 1970s to only 1.8 today.

In contrast, *indirect factors* are those that change the *context within which* women and couples make decisions about fertility and family size. For example, increasing girls' access to education results in lower fertility rates (see Figure 3.5). Young women who are better educated tend to marry later and have greater employment opportunities, both of which help reduce fertility. On average, globally, women with no formal education have 4.5 children. Those who have some schooling have an average of 3 children, and those who have some secondary schooling have an average of only 1.9 children. For women with advanced schooling, the average fertility rate drops to 1.7. In this case, investment in providing increased educational opportunities can be thought of as an indirect form of population control.

Figure 3.5: Education and fertility rates, 2012–2016

Data from select developed and less developed countries show a clear relationship between female education and fertility rates.



*Data from UNESCO Institute for Statistics, Data Center, n.d. (**http://data.uis.unesco.org**).*

Early Population Policies

As discussed earlier, by 1950 most developing countries were still in Phase 1 or 2 of the demographic transition. In the decades that followed, rapid improvements in medicine, sanitation, food supply, and water quality dramatically lowered death rates in these countries and triggered an exponential increase in population. The overall population of developing countries doubled from 1.7 billion in 1950 to 3.4 billion by 1980. Faced with a ballooning population and concerned with issues like food security, public services, and health, many developing countries undertook a variety of direct efforts to reduce fertility and slow population growth. China's one-child policy was the most publicized, but other countries like Brazil, Mexico, Iran, and Indonesia have also attempted to reduce fertility through monetary incentives and increased availability of contraceptives and family planning services.

India attempted a much more coercive approach in the 1970s. India's government declared emergency rule in 1975 and ordered local governments to set quotas for forced sterilizations—vasectomies for men and tubal ligation for women—for couples with more than three children. Couples who failed to undergo sterilization after their third child were threatened with fines and imprisonment, and in some cases police were sent to round up men and women and force them to undergo sterilization. In the last 6 months of 1976 alone, more than 6.5 million people were sterilized in India, and it's estimated that thousands may have died from infections associated with the surgery (Hartmann, 1995). The sterilization campaign proved so unpopular that it triggered protests and riots in various regions of the country. By 1977 public displeasure with the sterilization program helped lead to the electoral defeat of the ruling party and a backlash against family planning programs in general in India.

The Shift to an Indirect Approach

The year 1994 was a turning point in the field of population policy. In that year the United Nations International Conference on Population and Development (ICPD) was held in Cairo, Egypt. The ICPD was attended by close to 20,000 delegates representing government agencies, NGOs, and the media. The conference is widely credited with shifting the focus of population policy from direct and sometimes coercive measures to broader efforts to address the basic needs of the world's poorest residents.

The ICPD resulted in a consensus program of action containing over 200 recommendations and goals in the areas of women's health, development, and social welfare. These included providing universal access to primary education for girls and increased access to secondary and higher education for girls and women; providing universal access to reliable, affordable, and safe family planning services; reducing infant and maternal mortality; and increasing women's access to employment opportunities and financial credit. Many delegates to the ICPD believed

Pavel Rahman/Associated Press

Family planning programs, such as this one in Bangladesh, are an opportunity for women to learn about contraception and other family planning services.

that these actions would increase women's status in society and result in greater empowerment of women in making decisions about their own fertility.

Compared with earlier population policies, the ICPD recommendations emphasized *indirect* means of reducing fertility. Increased levels of education delay both the age of marriage and the age at which a woman has her first child. This narrows the *reproductive window* for women and results in lower fertility rates on average. Providing safe and affordable family planning services will also have an obvious impact on fertility.

Reducing infant mortality might seem to be a counterintuitive way to address population growth. However, fertility rates are usually highest in societies with high infant mortality, since parents seek to compensate for the expected loss of some of their children. Reducing infant and child mortality through better health care provides some assurance to parents that their children will survive to adulthood, and it reduces fertility rates in the process.

Finally, providing women with employment and small business opportunities has also been demonstrated to reduce fertility (Phan, 2013; Upadhyay et al., 2014). Efforts in this area often take the form of micro-credit or micro-lending programs that lend small amounts of money to individuals or groups of women to start their own business. Giving women more economic independence carries over to decisions about fertility, empowering them to resist spousal and societal pressure for large families. (For more on this, check out *Apply Your Knowledge: What Is the Connection Between Female Employment and Fertility Rates?*)

Apply Your Knowledge: What Is the Connection Between Female Employment and Fertility Rates?

Looking at some fertility rate data from around the world will help us learn more about some of the indirect factors that influence population growth and allow us to practice some strategies for analyzing data sets.

Figure 3.6 shows two charts with data on TFRs and factors that may be influencing those rates around the world. The charts contain data points from several different countries so that we can explore female employment and CO_2 emissions as possible influencing factors. Based on these charts, do you think female employment and CO_2 emissions are influencing TFRs? If so, can you explain how? Can you use this information to come up with any population management strategies?

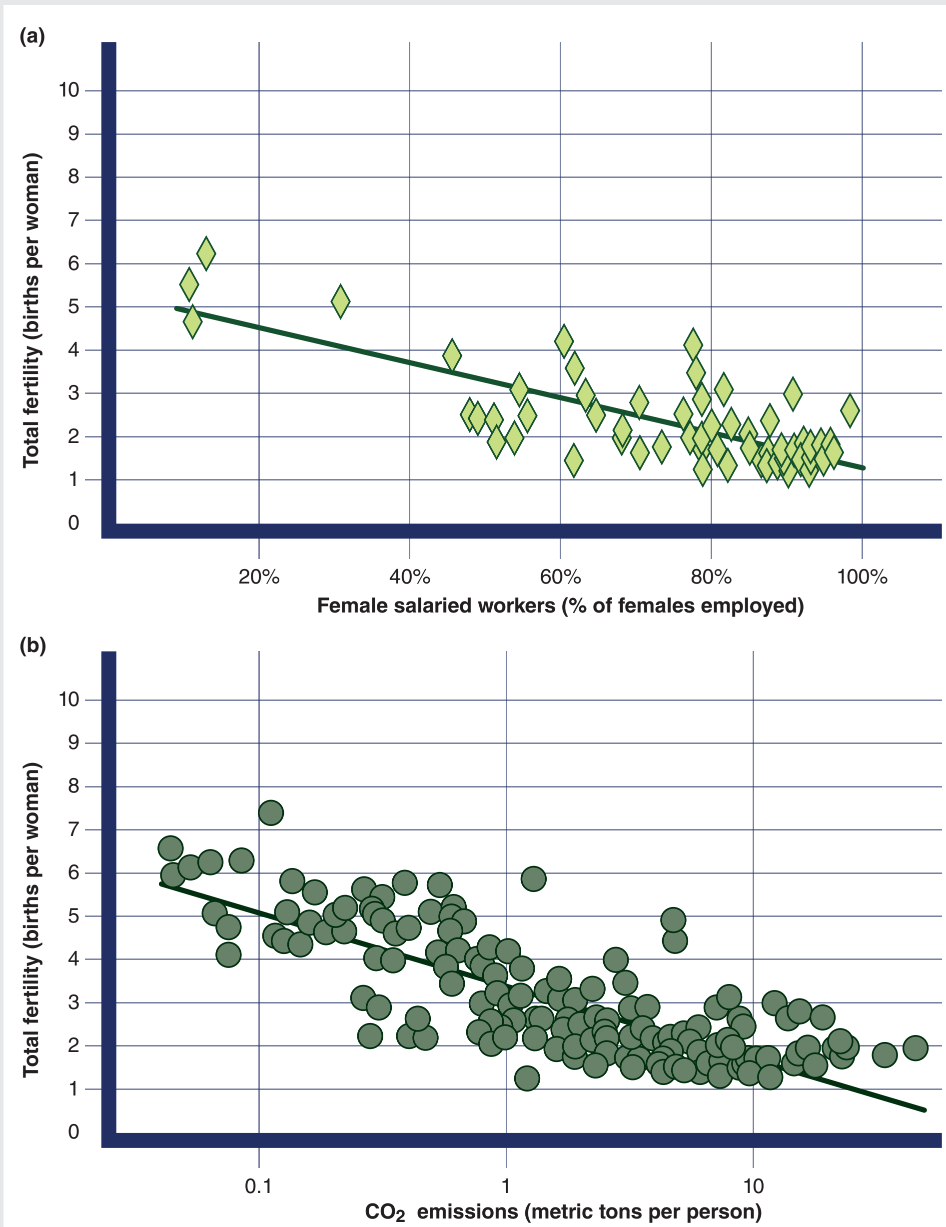
You might notice that these figures both seem to show strong trends in the data. It appears that countries with higher female employment tend to have lower fertility rates. It also appears that countries with greater CO_2 emissions tend to have lower fertility rates. Best fit lines (also called trend lines), like the ones seen in our figures, can be helpful tools for finding relationships like these. By definition, a best fit line traces a path through the middle of a data set. When a best fit line slopes upward or downward and most of the data points fall close to the line, this suggests that the two measurements are related somehow. Researchers say that the data is *correlated* when one of these relationships exists. In this example, it is safe to say that female employment and CO_2 emissions both appear to be correlated with fertility rates.

(continued)

Apply Your Knowledge: What Is the Connection Between Female Employment and Fertility Rates? *(continued)*

Figure 3.6: Female employment, CO_2 emissions, and fertility

Total fertility rates plotted against female employment (a) and CO_2 emissions (b).



*Data from "Children per Woman (Total Fertility Rate)," by Gapminder, n.d. (**http://gapm.io/dtfr**); "ILOSTAT," by International Labour Organization, 2019 (**https://www.ilo.org/ilostat**); "Fossil-Fuel CO_2 Emissions," by Carbon Dioxide Information Analysis Center, 2017 (**http://cdiac.ornl.gov/trends/emis/meth_reg.html**).*

(continued)

Apply Your Knowledge: What Is the Connection Between Female Employment and Fertility Rates? *(continued)*

We often expect to see correlated data when there is a cause-and-effect relationship at play. For example, our female employment and fertility data are correlated, and there is also a strong theory for how female employment might cause a decrease in a region's fertility rates. More women working means that more women are financially independent. With more financial freedom, more women might choose to delay or avoid getting married and having children.

This cause-and-effect relationship can also be supported with studies that have explored female employment in greater depth. In one recent example, researchers studied rural communities in Senegal. By surveying them about their family sizes and lifestyle choices, the researchers found that the relationship held up (Van den Broeck & Maertens, 2015).

When we have correlated data *and* supporting evidence of a cause-and-effect relationship, we might conclude there is a *causal relationship* between the two measurements in a data set. Causal relationships can be very useful from a policy standpoint. If we determined that a causal relationship exists between female employment and fertility, we might develop job-training programs and fair hiring regulations to exploit this relationship.

It is critical to realize that correlated data does not necessarily imply a causal relationship. As researchers, we have to remember the mantra "correlation is not causation" so that we do not draw conclusions based on relationships that do not exist. On the second chart, it appears that the countries with greater emissions have lower fertility rates. However, there is no obvious explanation for how CO_2 emissions might impact reproduction. Countries often undergo changes that impact both CO_2 emissions and fertility rates at the same time, but this does not mean that CO_2 emissions are causing reproductive changes. As a result, we have no reason to believe that we can change fertility rates by encouraging people to burn more fossil fuels.

When analyzing data sets, you need more than a statistical correlation in order to identify a causal relationship. You also need a strong theory and supporting evidence.

Overall, these indirect approaches also tend to reduce poverty, and there are clear statistical links between reduced poverty and lower fertility. The fundamental argument behind the ICPD program of action is that "development is the best contraceptive," as Indian politician Dr. Karan Singh once said (as cited in Mathai, 2008, para. 3). Investments in education, health care, sanitation, and economic opportunity are promoted as paying a "double dividend." Not only do they serve to lower fertility rates, they also meet social justice objectives of providing a better life for the world's poorest citizens.

Both direct and indirect efforts to lower fertility have been successful. With the exception of mainly countries in sub-Saharan Africa, fertility rates have fallen to near or even below the replacement rate in the majority of developing countries. But even as this has happened, there has been something of a shift in the debate over population growth and the environment. More and more observers are pointing to high material consumption rates in developed countries as the greatest threat to the global environment, as opposed to high population growth rates in developing countries. That debate is covered in Section 3.6, after the comparative case study of family planning approaches in Section 3.5.

3.5 Case Study: Population Policies in China and Thailand

China has perhaps the most well-known and controversial population control program in the world. China is currently the world's most populous nation, with a 2019 population of 1.39 billion people, roughly one fifth of the world's total. But it's possible that China's population would be closer to 2 billion today had it not taken steps to reduce fertility and birth rates more than 40 years ago. After suffering through famines that killed as many as 30 million people in the 1960s, China launched a number of family planning campaigns that culminated in a one-child-per-family policy in 1979. This policy relied on a variety of rewards and punishments to encourage compliance. Families with only one child were provided with better access to health care, education, housing, and employment opportunities. Families with more than one child lost these privileges and were also subject to fines. There were some exceptions to and differences in application of this policy. For example, rural couples were more likely to be allowed a second child compared to urban couples. By 2015 China had begun to relax the one-child rule, and all couples are now allowed to have two children.

While China's one-child policy was successful in rapidly reducing the country's fertility rates—from over 5 in 1970 to 1.8 today—it has also been criticized on human rights and other grounds. Zealous enforcement in the policy's early years often resulted in forced abortions and mass sterilizations such as those that occurred in India. In 1991, 12.5 million Chinese citizens underwent sterilization, oftentimes against their will and under threat of violence and official brutality. A cultural preference for sons has also led to high rates of selective abortions of female fetuses, large numbers of female babies being given up for adoption, and even female infanticide—the deliberate killing of a child within its first year. China has perhaps the most unbalanced male–female sex ratio in the world, with approximately 115 boys for every 100 girls. As a result, millions of Chinese men have been unable to find a spouse and have children. In China these men are known as *guang gun-er*, or literally "bare branches," since they are branches of a family tree that are unable to bear fruit.

As China was instituting its one-child policy, the Southeast Asian nation of Thailand was adopting a very different approach to population policy. Like China, in 1970 Thailand had high fertility rates (almost six children per woman) and a population that was increasing by more than 1 million people every year. The Thai minister of health at the time, Mechai Viravaidya, launched a humorous public relations campaign to increase the availability and use of contraceptives. He founded the Population and Community Development Association (PDA) to carry out this work. PDA workers crisscrossed the country handing out condoms, holding family planning education clinics, sponsoring condom balloon-blowing contests, and painting birth control advertisements on buses, billboards, and even the sides of water buffalo. The PDA used humor to encourage a more open discussion in polite Thai society about the use of contraception.

Jerry Redfern/LightRocket/Getty Images

The Population and Community Development Association in Thailand aims to educate the population about family planning by making contraception more accessible and encouraging positive discussions.

The association combined this campaign with projects to promote economic development and education in order to encourage families to consider having fewer children. By just about any measure, Mechai's campaign could be considered a success. Thailand's fertility rate is now only 1.5, and condoms are now affectionately known in that country as *mechais* in honor of Mechai's work.

3.6 Population Growth and Material Consumption

The link between population growth and environmental degradation would seem obvious. More people consume more energy, food, water, and resources. More people also generate more pollution and waste products. For these reasons, efforts to slow and eventually halt global population growth are often near the top of the agenda for many environmental organizations.

However, the relationship between population size and environmental impact is not always so clear. Some of the most sparsely inhabited regions are subject to some of the worst environmental degradation in the world, such as widespread deforestation in the Brazilian Amazon jungle. Meanwhile, some of the most densely populated regions, such as the island of Java in Indonesia or Machakos District in Kenya, have been practicing relatively sustainable resource management for decades or even centuries. This section will shift the discussion from a focus on demography and population policy to a review of the ways in which population levels and population change affect environmental conditions.

Population, Affluence, and Technology

In 1968, as the global population was swiftly climbing from 3 billion to 4 billion and beyond, ecologist Paul Ehrlich wrote a book titled *The Population Bomb*. Ehrlich argued that runaway population growth would result in increased starvation, social unrest, and even the collapse of some societies as human numbers exceeded the carrying capacity of the local environment. Ehrlich argued for quick and decisive action to limit further population growth, including some of the more drastic and direct population policies described in Section 3.4. In the years that followed the publication of *The Population Bomb*, the most dramatic predictions in the book did not materialize. Advances in agriculture and increased global trade in food products averted the kinds of widespread famines and food shortages that Ehrlich predicted, although small-scale famines were still a reality. In addition, Ehrlich, working in partnership with fellow ecologist John Holdren, began to consider how other factors beyond just the numbers of people could be affecting environmental conditions.

By the mid-1970s Ehrlich and Holdren were arguing that high rates of material consumption and affluence in wealthy countries may actually play a greater role in global environmental degradation than growing populations in poorer countries. They developed a simple equation called the **IPAT formula** (pronounced *i-pat*) to illustrate this argument. The *I* in the formula stands for the environmental *impact* of a given population. Impact is a function of three factors: population size (P), average affluence (A) or consumption rates per person, and the kinds of technology (T) available.

monkeybusinessimages/iStock /Getty Images Plus *stockimagesbank/iStock/Getty Images Plus*

In the image on the right, a father and daughter in rural India enjoy electricity for the first time. There is a wide variance in consumption patterns between the wealthiest and poorest people on the planet.

While poorer countries with high rates of population growth may be impacting the environment through the P factor, wealthy countries have a larger impact through the A factor of affluence and consumption. The technology, or T, factor manifests in different ways. For example, affluence allows a population to invest more resources in things like pollution control and energy efficiency technology, potentially reducing environmental impact. At the same time, affluence could also result in fundamental changes in the kinds of technologies used by the average citizen, sometimes with profoundly negative effects on the environment. For example, as countries like China and India have become more affluent, many individuals have shifted from relying on bicycles to relying on motorcycles and automobiles. *Close to Home: Examining Consumption* provides another example of how affluence and consumption affect the environment.

Close to Home: Examining Consumption

Many adult Americans begin their day with a cup of coffee, but this morning ritual can have significant environmental repercussions. In fact, many of our lifestyle choices consume resources and affect the environment in ways that are hard to see.

Coffee is the most popular beverage in the world, but coffee beans cannot be grown just anywhere. Crops do best in equatorial regions with consistent sunlight, and many varieties require higher altitudes to thrive. As a result, a handful of regions with suitable conditions are growing coffee for the entire world, and this can put a big strain on water and soil in these environments. Coffee plants are also more productive when they are "sun cultivated" rather than grown in natural, shaded environments, so many of these locations are cutting down forests to maximize sunlight.

(continued)

Close to Home: Examining Consumption *(continued)*

Even though growing regions are heavily impacted by global coffee consumption, they do not always receive the majority of the benefits. On average, coffee growers receive about 10% of coffee revenue (Blacksell, 2011), and many producers can barely meet their daily needs. Low wages also encourage producers to grow coffee as cheaply and as quickly as possible, without taking the long-term health of their environment into account.

As more consumers have become aware of these issues, the coffee industry has responded with new products. Fair trade coffees try to ensure that growers get paid adequately for their coffee beans, and more retailers are offering shade-grown varieties that can result in less environmental destruction. Several organizations now provide certifications to help consumers identify these better alternatives. The Smithsonian Bird Friendly certification ensures that forests are protected during coffee production. The Rainforest Alliance certification indicates that growing practices and compensation both meet strict sustainability standards. Fair trade options might have a Fair Trade USA symbol, and many organic options are identified with the familiar USDA stamp from the U.S. Department of Agriculture.

andresr/E+/Getty Images Plus

A coffee plantation in Colombia. Fair trade coffee growers ensure that their workers are paid adequately.

Affluence is an important factor in determining how much coffee gets consumed and how much environmental damage occurs as a result, but it also influences where these environmental impacts occur. Compare the Worldmapper map on global coffee production and the Worldmapper map on global coffee consumption. According to this data, who do you think is enjoying the majority of the world's coffee, and who do you think is suffering the worst of its environmental impacts?

What is striking about these maps is that several of the largest coffee-producing regions are not major consumers. Growers in places like Vietnam, Honduras, and Colombia have found that their coffee harvests provide the greatest benefit when they are sold to consumers in more affluent nations like the United States, Germany, and Japan. The places that consume coffee often do not experience the environmental consequences. Meanwhile, less affluent regions are taking on environmental burdens for economic gain.

Coffee is not the only form of consumption that has spatially removed consequences. Food, clothing, electronics, and many other daily consumables have a good chance of affecting environments in some other part of the world. It is important that we understand how these production chains operate so that we can begin to develop better ways of meeting our daily needs. Can you come up with any strategies for reducing the impacts of your consumption patterns? Are you aware of any goods that are produced in more environmentally friendly ways than others? Are there ways of keeping our environmental impacts a little closer to home? Finally, are there ways you can consume less and still have the lifestyle you desire?

The IPAT formula helps us consider and analyze the wide gap that exists in resource consumption patterns between the wealthiest and the poorest people on the planet. For example, it's estimated that the world's richest 500 million people, representing just 7% of the global population, produce 50% of worldwide carbon dioxide pollution. In contrast, the poorest 50% of the global population produce just 7% of worldwide carbon dioxide pollution. Meanwhile, an average citizen of a country like the United States consumes nearly 40 times the amount of energy that typical person in Bangladesh consumes. These kinds of statistics illustrate that *overpopulation* may be less of a concern than *overconsumption*. What the IPAT formula really helps us do is see how the factors of population, affluence, and technology *interact* and *interrelate* to determine the overall environmental impact of a given population.

Revisiting the Environmental Footprint

Recall from Chapter 1 that an environmental footprint is a measure of how much land and water is required to produce the resources and absorb the waste products of a given person or group of people. Environmental footprints can be calculated at the level of the individual, family, business, university, city, state, or nation—or even the entire world. In one sense, the environmental footprint measure is the outcome of the IPAT formula. By calculating the environmental footprint for a specific country, we can see how the *combination* of population size, affluence/consumption, and technology choices shape that country's impact on the environment. And by looking at the differences in environmental footprints across countries, we can gain a better idea of whether population or affluence/consumption is the biggest factor in shaping the environmental footprint of that nation.

Global Footprint Network Approach

The Global Footprint Network (GFN) is a research organization that calculates and publishes data on environmental footprints for different countries around the world. The GFN also works to find ways for countries, organizations, and even individuals to reduce their environmental footprints and have less of an impact on the environment. The GFN examines the environmental footprint from both the demand side and the supply side. On the demand side, the environmental footprint accounts for our consumption of plant-based food and fiber, livestock/animals, fish products, timber/forest products, space for buildings and infrastructure, and the space needed to absorb our wastes, especially carbon dioxide emissions. On the supply side, *biocapacity* is a measure of the productivity of the land and resources available to provide for human needs. In short, the environmental footprint measures the "demand for nature" of a given population, while biocapacity measures the "supply of nature" available to that population on a sustainable basis.

By comparing a population's environmental footprint to its biocapacity, the GFN approach can determine whether that group of people is running an *ecological deficit* or if the group still has an *ecological reserve*. An **ecological deficit** occurs when a population consumes resources and generates wastes at a rate that exceeds what its ecosystems can provide or absorb on a sustainable basis. In contrast, an **ecological reserve** occurs when a population's biocapacity exceeds its footprint: The population is consuming resources and generating wastes at a rate that *is within* what its ecosystems can provide or absorb on a sustainable basis.

"And may we continue to be worthy of consuming a disproportionate share of this planet's resources."

Lee Lorenz/Cartoon Collections

Recall from Chapter 1 that natural capital is both the resources and services provided by nature. Also recall that sustainability is development that occurs in a way that does not deplete or use up natural capital. Essentially then, when a nation or group of people has an environmental footprint that exceeds its biocapacity—that is, when it is running an ecological deficit—it has to either import natural capital from other places or liquidate its own natural capital. In other words, measuring environmental footprints against biocapacity is one way to determine whether a population is operating in a way that is sustainable.

Comparing Different Countries

There are multiple ways to compare environmental footprints between countries and populations, but comparing the average footprint of citizens of different countries will help us examine how population size interacts with levels of affluence and consumption to determine a country's impact on the environment. Table 3.3 lists 25 different countries and the average environmental footprint and biocapacity per person, the total environmental footprint and biocapacity per country, the ecological deficit or reserve, and data on fertility rates, population growth, and total population per country. Note that Table 3.3 lists the countries in order of the size of their environmental footprint per person, starting with the smallest (Haiti). You can also explore the Ecological Footprint Per Person map at the Global Footprint Network's Ecological Footprint Explorer.

Table 3.3: Environmental footprint and population data for 25 countries

Country	Environmental footprint (ha/person)	Biocapacity (ha/person)	Total environmental footprint (million ha)	Total biocapacity (million ha)	Ecological deficit or reserve (million ha)	TFR	Population growth rate	Total population (millions)
World	2.75	1.63	20,509	12,169	−8,340	2.4	1.2	7,621.4
Haiti	0.68	0.32	7	4	−3	3.0	1.7	10.8
Bangladesh	0.84	0.41	137	66	−71	2.1	1.4	166.4
Zambia	0.95	1.88	16	31	15	5.2	3.1	17.7
Uganda	1.06	0.48	44	20	−24	5.4	3.2	44.1
Nepal	1.07	0.56	31	16	−15	2.3	1.4	29.7
India	1.17	0.43	1,547	566	−981	2.3	1.4	1,371.3
Tanzania	1.22	1.02	68	57	−11	5.2	3.3	59.1
Philippines	1.33	0.55	137	57	−80	2.7	1.5	107.0
Cuba	1.78	0.81	20	9	−11	1.6	0.2	11.1
El Salvador	2.06	0.6	13	4	−9	2.3	1.3	6.5
Vietnam	2.12	1.02	201	96	−105	2.1	0.9	94.7
Peru	2.24	3.68	71	117	46	2.4	1.4	32.2
Thailand	2.49	1.18	171	82	−89	1.5	0.2	66.2
Brazil	2.81	8.7	584	1,807	1,223	1.7	0.8	209.4
South Africa	3.15	0.96	176	54	−122	2.4	1.2	57.7
China	3.62	0.96	5,195	1,374	−3,821	1.8	0.5	1,393.8
Malaysia	3.92	2.26	122	70	−52	1.9	1.1	32.5
Japan	4.49	0.58	574	74	−500	1.4	−0.3	126.5
Germany	4.84	1.62	397	133	−264	1.6	−0.2	82.8
Saudi Arabia	6.23	0.42	201	14	−187	2.4	1.4	33.4
Australia	6.64	12.27	160	296	136	1.7	0.6	24.1
Denmark	6.8	4.17	39	23	−16	1.8	0.2	5.8
Canada	7.74	15.12	281	549	268	1.5	0.3	37.2
United States	8.1	3.65	2,611	1,175	−1,436	1.8	0.3	328.0
Luxembourg	12.91	1.24	7	0.7	−6	1.4	0.3	0.6

Sources: "2018 World Population Data Sheet," by Population Reference Bureau, 2018 (https://www.prb.org/wp-content/uploads/2018/08/2018_WPDS.pdf); "Ecological Footprint Explorer," by Global Footprint Network, 2018 (http://data.footprintnetwork.org/#/compareCountries).

On average, across the entire world, each person has an environmental footprint of 2.75 hectares (ha), or roughly 7 acres. In other words, each of the 7.7 billion people on the planet needs an equivalent of about 7 acres to provide the resources he or she needs and absorb the waste products he or she generates. However, this average masks significant variations in the environmental footprint between nations and peoples. For example, in countries like Haiti, Bangladesh, and Zambia, the environmental footprint per person is less than 1 hectare (2.47 acres). In contrast, in countries like Luxembourg, the United States, and Canada, the environmental footprint per person is over 7 hectares (or 17.3 acres).

While there are reasons to be concerned, from an environmental standpoint, about countries like Tanzania, Zambia, and Uganda because of their high fertility and population growth rates, their environmental footprints provide a somewhat different perspective. Based on the environmental footprint data presented in Table 3.3, an average American uses the Earth's resources and natural capital at a rate that is 7 to 8 times greater than an average Zambian, Ugandan, or Tanzanian. The environmental footprint concept allows us to broaden our focus beyond just the absolute numbers of people in a given country and also to consider the resource and material consumption patterns of the people in that country.

Table 3.3 also provides data on the average biocapacity available per person, as well as the total environmental footprint and available biocapacity for each of the countries listed. Comparing the average environmental footprint to the average biocapacity, or a country's total environmental footprint to its available biocapacity, allows us to see which countries are operating an ecological deficit.

Globally, the average environmental footprint is 2.75 hectares, whereas biocapacity is only 1.63 hectares. This suggests that we are running a global ecological deficit. Some of the countries with relatively low environmental footprints also have quite limited biocapacity. For example, Haiti, the Philippines, India, and Cuba all have environmental footprints that are less than 2 hectares per person, but in each case their average biocapacity per person is even lower, suggesting that all these countries are running an ecological deficit. In contrast, some of the countries with relatively high ecological footprints also have higher biocapacity. Australia and Canada, in particular, both have footprints that are large but still lower than their biocapacity, suggesting that they still have some ecological reserve. Both of these countries have large land areas and relatively low populations, making them something of an exception to the rule. You can also explore the Ecological Deficit/Reserve map at the Global Footprint Network's Ecological Footprint Explorer.

Learn More: Worldmapper

Typically, maps are used to show us where a city, state or country is located relative to other locations. But at the website https://worldmapper.org/, maps are used to display information about countries beyond just their physical location. Worldmapper does this by distorting the size of a country to represent a characteristic of that country's economy or population. For example, the *Close to Home: Examining Consumption* feature references Worldmapper maps of coffee consumption and production, which illustrate that coffee is consumed in different places from where it is produced. Other maps related to the environment and the IPAT equation include representations of carbon dioxide emissions, biodiversity hotspots, and human development. Visit https://worldmapper.org and have a look at the world in a whole new way.

Global Consequences

The GFN estimates that over 80% of the world's population lives in countries that are running ecological deficits. The GFN also estimates that the global ecological deficit is so bad that at our current rates of consumption, waste generation, and natural capital usage, we would require the equivalent of 1.7 Earths to meet our needs without running a deficit. Since we are obviously not in a position to import resources or biocapacity from other planets, this can only mean that we are liquidating natural capital faster than it can regenerate. This does not meet the standard for sustainability, and it means that we are undermining our own future in the process.

To call attention to this situation, the GFN established what it calls Earth Overshoot Day every year. Earth Overshoot Day is the date each year when human consumption of natural capital exceeds what's available on a sustainable basis for that year. Ideally, humanity should use no more than what it needs each year by December 31. In 2000 Earth Overshoot Day came in late September, meaning humanity had used all of the resources and natural capital available for 2000 *on a sustainable basis* by late September. Today our population and resource consumption has grown so that Earth Overshoot Day now falls on August 1. Resource and natural capital consumption that occurs from then until the end of the year represents natural capital liquidation and a further move away from sustainability.

Bringing It All Together

Every environmental issue and topic that the remaining chapters of this book will cover is affected in some way by population change and rates of resource and material consumption. Global population has grown from under 1 billion in 1800 to over 7.7 billion today and is projected to increase to around 11 billion by 2100. The addition of 10 billion more people over a 300-year period has ushered in the Anthropocene, the age of humans. High rates of material and resource consumption among the more affluent members of global society have furthered the far-reaching impacts that humans are having on the global environment.

As the focus shifts in subsequent chapters to specific environmental issues and concerns, keep in mind some of the key lessons from this chapter. First, despite dramatic declines in fertility rates worldwide, human population growth continues apace. Second, it's important to consider levels of affluence and consumption, in addition to absolute numbers of people, in assessing the overall environmental impact of a given population. Third, it will take enormous progress in *both* slowing and stabilizing population as well as in reducing resource and material consumption if we are to try to achieve sustainable development. At present, in an ecological sense, we are living way beyond our means, and we are able to do this only because we are consuming and depleting natural capital resources at rates that are not sustainable. In essence, we are selling off our natural assets to maintain our current way of life. This cannot go on forever. As we shift to a discussion of food, forests, water, oceans, energy, and atmosphere, try to challenge yourself to think what you as an individual, and we as a broader society, can do to shift to a more sustainable approach to resource and environmental management.

Additional Resources

Demographics

There are a number of online sources that allow you to see how world population is changing every second of every day. The first two links listed below are basic population clocks, while the third provides a more in-depth dashboard view of the data. Note that there are slight discrepancies in the population clock numbers. Why do you think that might be? Different methods? Different assumptions? Different sources of data?

- https://www.census.gov/popclock/
- https://www.worldometers.info/world-population/
- https://www.unfpa.org/data/world-population-dashboard

You can find a lot of basic demographic data and other useful information about population trends and issues at these websites.

- https://www.prb.org/
- https://www.un.org/en/development/desa/population/index.asp
- https://www.census.gov/topics/population.html

The Demographic Transition

This website provides an interactive lab/simulator that allows you to change the demographic characteristics (such as birth and death rates) of a sample population and see what the resulting effects would be.

- http://www.learner.org/courses/envsci/interactives/demographics/demog.html

Population Policy and Fertility Control

There are many good TED Talks on the subject of population and the environment, but here are three that are definitely worth watching, including one on Thailand's "Mr. Condom."

- Hans Rosling: Global Population Growth, Box by Box:
  https://www.youtube.com/watch?v=fTznEIZRkLg
- Hans Rosling: The Good News of the Decade?:
  https://www.youtube.com/watch?v=OT9poH_D2Iw
- Mechai Viravaidya: How Mr. Condom Made Thailand a Better Place:
  https://www.youtube.com/watch?v=EL9TBKSdHXU

It's been 25 years since the ICPD conference in Cairo, Egypt, but that event is still remembered as a turning point in how the world viewed population growth and development. You can learn more about the ICPD and what it accomplished at these sites.

- https://www.prb.org/whatwascairothepromiseandrealityoficpd
- https://www.unfpa.org/icpd

These links provide a good background on China's one-child policy and how that policy has recently begun to change.

- https://www.washingtonpost.com/world/asia_pacific/beijings-one-child-policy-is-gone-but-many-chinese-are-still-reluctant-to-have-more/2019/05/02/c722e568-604f-11e9-bf24-db4b9fb62aa2_story.html
- https://www.theguardian.com/world/2019/mar/02/china-population-control-two-child-policy

The PBS series *NOVA* aired an interesting series called *World in the Balance*. The website for this series has some interesting links, including a story about how government propaganda was used to change minds about fertility and family planning in certain countries ("Population Campaigns") and how material consumption differs among families in different countries ("Material World").

- https://www.pbs.org/wgbh/nova/worldbalance

The United Nations Population Fund published an interesting report that looks at future population trends from the perspective of a 10-year-old girl.

- https://www.unfpa.org/sites/default/files/sowp/downloads/The_State_of_World_Population_2016_-_English.pdf

Population Growth and Material Consumption

The Global Footprint Network, with the slogan "measure what you treasure," is the go-to site for all kinds of information on the environmental footprint concept, footprint data, and what the world can do to bring its footprint in line with biocapacity.

- https://www.footprintnetwork.org

Key Terms

age-structure pyramid A graphical illustration of how a specific population is broken down by age and gender. Also known as a population pyramid.

agricultural period The period in human history that dates from about 10,000 years ago to about 200 years ago. The domestication of plants and animals, selective breeding of nutrient-rich crops, and development of technologies like irrigation and the plow greatly increased the quantity and security of food supplies for the human population.

crude birth rate (CBR) The number of live births per 1,000 people in a given population over the course of 1 year.

crude death rate (CDR) The number of deaths per 1,000 people in a given population over the course of 1 year.

demographic momentum The tendency for a population to continue growing even after its fertility rate declines, due to the number of young people in the population.

demographic transition A model used by demographers to explain and understand the relationship between changing birth rates, death rates, and total population.

demography The statistical study of human population change.

ecological deficit A condition that occurs when a population consumes resources and generates wastes at a rate that exceeds what its ecosystems can provide or absorb on a sustainable basis; when a population's footprint exceeds its biocapacity.

ecological reserve A condition that occurs when a population consumes resources and generates wastes at a rate that is within what its ecosystems can provide or absorb on a sustainable basis; when a population's biocapacity exceeds its footprint.

emigration The act of people moving out of a given population.

immigration The act of people moving into a given population.

industrial period The period in human history brought about by the introduction of automatic machinery, starting around the mid-18th century for some countries and continuing into today.

IPAT formula An equation developed by Paul Ehrlich and John Holdren that illustrates that environmental impact (I) is a function of population size (P), average affluence (A) or consumption, and choices in technology (T).

net migration rate The difference between immigration and emigration per 1,000 people in a given population over the course of 1 year.

preagricultural period The period in human history that dates from over 100,000 years ago to about 10,000 years ago. During this time, humans developed primitive cultures, tools, and skills and slowly migrated out of Africa to settle Europe, Asia, Australia, and the Americas.

rate of natural increase The rate of population growth; in a given population, birth rates minus death rates, excluding immigration and emigration.

replacement rate The number of children, or total fertility rate (TFR), needed to "replace" the parents and maintain a certain population.

total fertility rate (TFR) The average number of children an individual woman will have during her childbearing years (currently considered to range from age 15 to 49).