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Enough Already? Linking Science, Geography, Mathematics, and Sociology Through Population Study

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Comments
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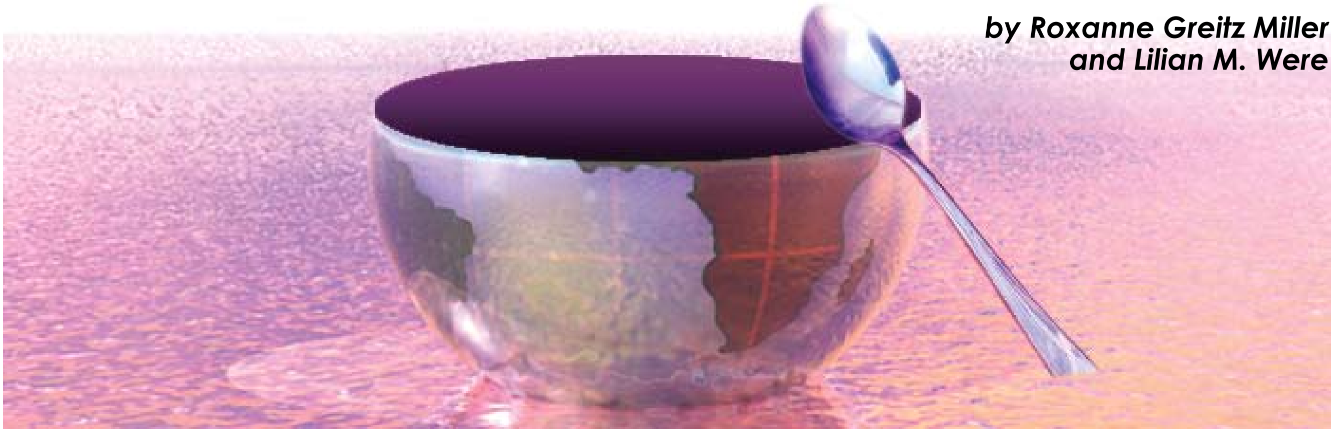
Enough already? Linking science, geography, mathematics, and sociology through population study

by Roxanne Greitz Miller and Lilian M. Were



In several previous Issues In-Depth columns, science topics deeply affected by population size—such as climate change, fuel and agricultural resources, and ecology—have been discussed. In this column, we will discuss the issue of population growth in developed and developing countries, why this is an important topic to discuss with young adolescents, and how interdisciplinary connections can be made between science and several other subject areas through an examination of populations across the globe.

Vocabulary primer

When studying populations, some key terms and concepts must first be understood.

Birth rate—average annual number of live births per 1,000 inhabitants of a certain geographic area; also known in some sources as crude birth rate (CBR).

Death rate—average annual number of deaths per 1,000 inhabitants of a certain geographic area; also known as crude death rate (CDR), morbidity, or mortality rate.

Population growth rate—rate of national growth expressed as a percentage for each country, commonly between about 0.1% and 3% annually, and is broken down into *natural growth* and *overall growth*. *Natural growth* represents the percentages of births and deaths in a country's population and does not take into account migration; *overall growth* takes migration into account.

Total fertility rate—the total number of children the average woman in a population is likely to have based on current birth rates. The average varies widely depending on nation and currently ranges from approximately 1.4 children per woman in Europe to 5.2 children per woman in Africa (combined average of all nations per continent).

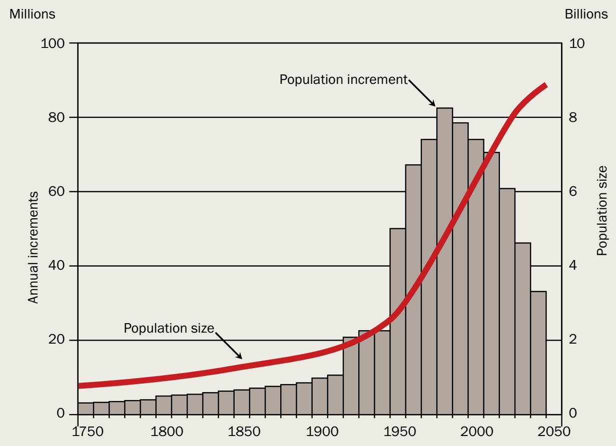
Replacement rate—number of children each woman needs to have to maintain current population levels, known as zero population growth, for her and her partner. Because children must live to reproduce in order to complete the cycle, replacement rate is always greater than 2 (one child to replace mother, one to replace father) due to deaths occurring prior to reproduction. Replacement rate is currently 2.1 children per woman in most developed nations where medical care is good and nonnatural causes of death (i.e., war) are low. In developing nations where medical care is lacking and nonnatural causes of death are higher, such as in some African nations, replacement rate is as high as 3.5 (Espenshade, Guzman, and Westoff 2003).

Carrying capacity—the maximum number of individuals that can be provided for within a certain geographic area without compromising the population in the future; referred to as *K* by biologists and ecologists.

Double trouble?

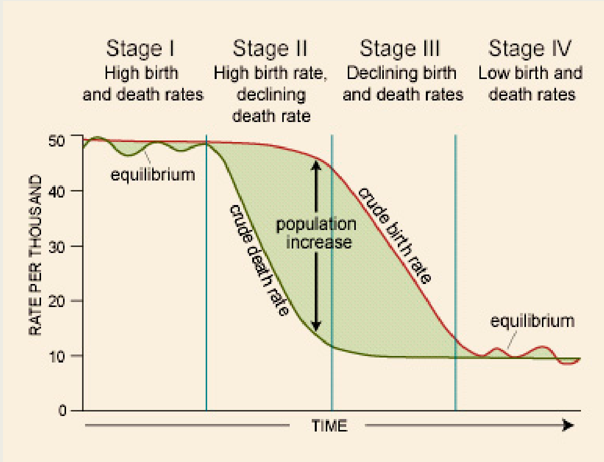
Doubling time, the length of time it takes for a population to double in size, has been dramatically shrinking

FIGURE 1 Long-term world population growth, 1750–2050



Source: United Nations Population Division, "The world at six billion." *www.un.org/esa/population/publications/sixbillion/sixbilpart1.pdf*

FIGURE 2 Demographic transition model



Source: Population Reference Bureau

over the last two centuries. While it took 304 years to go from one-half billion to 1 billion people in the world between the years 1500 and 1804, it is estimated that it will only take 51 years for the world's population to double from 4 billion in 1974 to 8 billion in 2025. This decrease in doubling time over the past several centuries is due to a larger population of young adults, increased availability of food and shelter, the capacity for migration (moving from areas where resources are poor to areas where they are better), and technological improvements in sanitation and health care leading to higher birth rates and lower death rates.

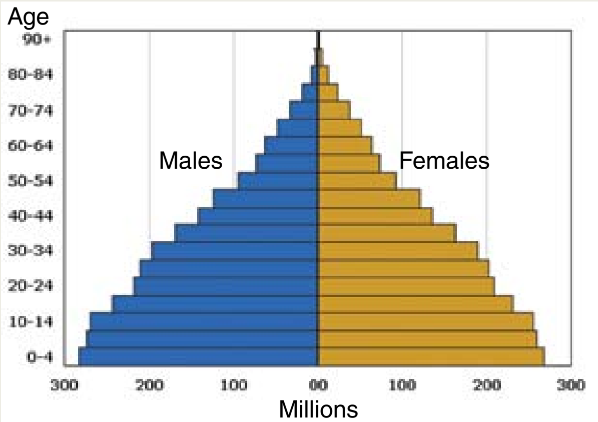
The decrease in doubling time—and the exponential increase in population over the last 100 years—means the Earth will be faced with having to support an estimated 9.3 billion people by the year 2050. Whether the planet can sustain the impact of so many people—and at what standard of living—is uncertain.

It has been suggested that the Earth's resources are enough to sustain only about 2 billion people, far below the current world population of 6.6 billion, at a typical European standard of living. How, then, does the world currently support its 6.6 billion people? The answer is that few people are provided with many resources, while many people are provided with few. The most populous continents (Asia and Africa) consist of many developing nations where people consume far less than the European standard. It is this inequality between living standards that accounts for Earth's current population and the apparent supply of resources in some areas and lack thereof in others. Of special note is the fact that the United States uses, on average, twice as many resources per person than Europe.

If looked at without respect to living standards, the current world population of 6.6 billion is consuming about 25% more resources than the Earth is producing. In simpler terms easy for the middle school student to understand, in the 12 months of 2006 we consumed the resources that it took the planet about 15 months to produce (WWF 2006). If looked at purely mathematically, a scenario such as this has a definite end point in time where the planet's resources will be depleted to a point where global population will no longer increase—and will inevitably decrease—until equilibrium between resources and population size is reached. A classic example of this situation, and one relatively easy for students to understand, is found in the story of reindeer introduced to St. Matthew Island (Klein 1968).

In 1944, 29 reindeer were introduced to uninhabited St. Matthew Island, located in the Bering Sea Wildlife Refuge. The reindeer exploited the high quality and quantity of the forage available on the island by increasing their population rapidly, due to a high birth rate and low mortality. By summer 1963, the reindeer population was estimated at 6,000. However, this number could not be sustained by the rapidly diminishing resources, and underwent a crash die-off the following winter to less than 50 animals. The reindeer population had exceeded its carrying capacity. By the 1980s, no reindeer continued to live on the island. Food supply, through its interaction with climatic factors, was the dominant population-regulating mechanism.

FIGURE 3 World population by age and gender, 2004



Source: United Nations Populations Division, World Population Prospects, The 2004 Revision. www.un.org/esa/population/publications/WPP2004/wpp2004.htm.

Demographic transition

Human populations, of course, can employ conscious decision making to issues related to population growth by limiting resource consumption and also limiting birth rates. Humans can also choose to increase birth rates because of the likelihood of children's deaths and the need for child labor or children to care for parents in their elder years. The stages of human population change, from times of high birth and death rates to low birth and death rates, are described by a model called *demographic transition* (Figure 2). Demographic transition of human populations is linked to economic development of a country from preindustrial to an industrial economy.

In Stage I, typical of early developing nations and preindustrial populations, birth and death rates are high due to limited food supply, poor medical care, and other sources of population instability such as war. In Stage II, typical of developing countries, some degree of prosperity is reached; birth rates are high and death rates are low, typical of populations that are experiencing wider access to health care, other resources, and greater stability. In Stage III, birth rates begin to decline, sometimes indicating a sensitivity of the population to depletion of resources or to the personal incentives to limiting births, such as are found in countries where governmental programs/incentives limiting reproduction are in place and contraception is widely available. In Stage IV, a relative equilibrium of low birth and low death rates is reached. Most economically developed countries such as in western Europe and North America are now in Stage IV, while the majority of developing countries—those containing the most people—are in Stages II or III (RAND Corporation 2000).

Population growth and distribution

Populations can be represented using graphs called population pyramids, which place males and females in different age groups ranging from oldest (on top) to youngest. In Figure 3, the world population in 2004 is represented.

Currently, the world has more young people, and particularly young women, than ever in recorded history. This is significant because the potential for population growth resides with the young, and particularly with young women, based on biological factors related to reproductive capacity. Additionally, the majority of the world's total population is found in developing nations in Stages II or III of demographic transition, which have higher total fertility rates than countries in Stage IV (see Figure 4). Therefore, at the present time, the world is facing the greatest potential for population growth ever in its recorded history.

Saving graces?

In the 1960s, it was proposed that technology would be able to "save" the Earth from the problem of overpopulation by making available new resources (primarily energy and agricultural) to sustain the demand. In the 1980s, attention was focused on renewable resources, those that could be replaced after use. In recent years, it has been recognized that while technology and use of renewable resources assist in reducing human impact, they cannot be relied upon as absolute measures that will assure humankind's continuance.

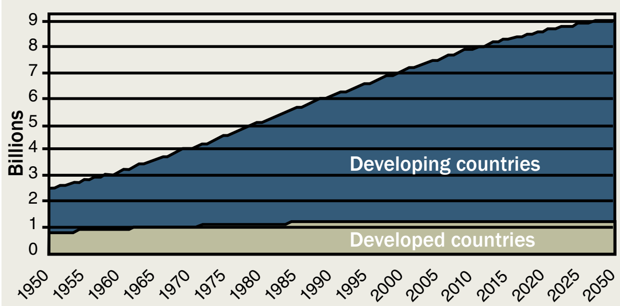
Renewable resources, such as timber, topsoil, and some types of groundwater, take a significant amount of time to develop to the same magnitude as that which was originally consumed. To illustrate, in the specific case of topsoil, it is now considered nonrenewable by many because it takes so much more time (hundreds of years) to create topsoil than to use it.

Recycling technology has been discussed previously in this column (see *Science Scope* December 2006 issue). While the impact of use of nonrenewable resources, such as metals, can be decreased, there are technical and economic issues that limit its effectiveness. For instance, while a certain material may be recycled, the cost may be so prohibitive that once the original supply is exhausted it is more economical to resort to alternative materials. Additionally, the degradation of certain materials during recycling makes them unsuitable for the same application, placing constraints on reusing a recycled material for the same end use.

Another proposed technological argument is that through better agricultural technologies, we will be able to produce more food to feed the world. Certainly, agricultural technology (e.g., the green revolution) has increased food yield (see April/May 2007 column). However, there are two very basic limiting factors on agricultural supply. There is a basic limit to the amount of land on Earth available for agriculture; in many nations, it is estimated that agriculture already occupies the vast majority of land that can be farmed, and in certain areas, the yields accrued from the green revolution cannot be increased beyond what is currently being produced. Water is another limiting factor affecting agriculture supply in many parts of the globe, and countries lacking sufficient rainfall have to rely on irrigation to boost supplies. Time is also a limiting factor: It takes more time to produce food than it does to consume it, so efforts today to increase agricultural yield will not benefit today's hungry. The same time constraints apply to resources such as water and lumber.

Trade also will not solve the problem of limited resources. Currently, populations are able to exceed their local carrying capacities by importing resources. People living in urban areas, for example, import nearly 100% of their food supply. However, as population increases, exporters of resources will need to reduce their exports in order to support their own domestic populations. In April 2008, India halted non-basmati rice exports out of concern for its nation's own food supplies. This same situation is predicted to face the United States by 2025, when it is estimated that the U.S. population will consume all of its food resources domestically, leading to devastating consequences for countries that now rely on U.S. sources for their food. Ultimately, resources will be exhausted or those few that do remain will be extremely costly and out of reach of most of the world's population.

FIGURE 4 **Global population growth: A developing-country phenomenon**



Source: United Nations Populations Division, World Population Prospects, The 2004 Revision, medium variant.

The greatest hope

The most promising method for decreasing the world's population lies particularly in educating young females across the globe. It is for this reason that examining population growth and diminishing resources is so appropriate for adolescents, who are on the cusp of reproductive capacity. It is during adolescence that students begin to think about their adult lives and make decisions that will affect their futures.

Total fertility rate is indirectly proportional to level of education completed. Plainly speaking, the higher the average level of education, the lower the average number of children per woman, and there is a decreased replacement rate as well. Education represents opportunity in most societies. Those who have higher education levels are able to provide for their families, move to areas where resources are more plentiful, reduce unnecessary resource consumption/waste, and invest more resources in the children that they do have. While many aid programs concentrate on providing contraception and food to those in need, in the absence of increasing educational opportunities for the young—and particularly for young females—these types of assistance in isolation will not be able to make the dramatic long-term changes necessary to address the limited-resource issues facing the world in the next 50 years.

Connecting to the classroom

Population studies allow for integrating science, mathematics, geography, and sociology in a meaningful way that can affect students' lives and future decisions. The graphs shown above illustrate a variety of methods to represent data visually, and allow teachers to use graphs as aids for science process skills such as predicting, observing, hypothesizing, and explaining. Studying different world countries and the issues facing them with respect to resources and their populations integrates geography and also allows students to compare common characteristics of their home country with others across the globe. Sociologically, students can discuss the reasons why individuals and various countries take different approaches to encouraging or limiting reproduction.

One of the most comprehensive resources available, including middle and high-school level resources, can be found at the Population Reference Bureau website, *www.prb.org/educators.aspx*. At this site, teachers can find interactive lesson plans, fact sheets, PowerPoint presentations, and background information on the topics discussed here as well as additional relevant topics.

Closing thoughts

It must be said that any study of population growth must be undertaken with sensitivity to world cultures other than one's own, and to different cultures within one's own country as well. It is important that teachers be conscious of the multiple perspectives across the globe regarding reproduction, and the differences in family structure, traditions, and religious views—and that teachers educate their students in respectful ways. The point of studying population growth is not to pass judgment on different societies—it is to educate today's students about the anticipated population trends of the future, and the ways in which students can make the best choices now and in the future.

Acknowledgment

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