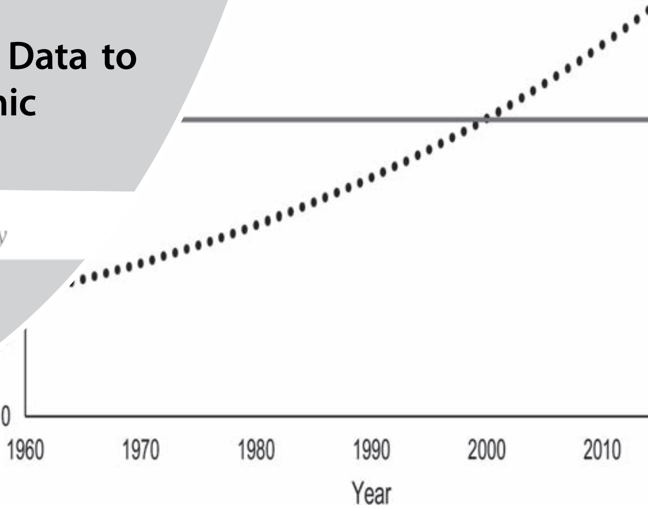
INQUIRY & INVESTIGATION

Use of U.S. Census Bureau Data to Expose Students to Dynamic Population Growth

RECOMMENDED FOR *AP Biology*



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Abstract

Global human population size and understanding how it has changed and will change in the future are important concepts for students. Here I describe exercises that use online databases provided by the U.S. Census Bureau to show students how both population size and the rate of change vary over time. In the first exercise, the U.S. population clock is used to calculate daily birth, death, and migrant and death rates, and how the world population clock is used to calculate the rate of change. These rates can be used to predict what the population size would be if the rates remained unchanged for a predetermined time interval. In the second exercise, historical data are used to determine the years with the most change in U.S. and world population size, then calculate how much larger the current population would be if those historical rates of change remained constant. These exercises have improved quantitative literacy while showing students current and historical trends in human population.

Key Words: *databases; overpopulation; global population size; population clock; quantitative literacy; U.S. population size.*

○ Introduction

Background

On October 31, 2011, the United Nations symbolically declared a female baby in the Philippines the seven billionth human on earth. Although the estimated global human population size can vary by source, all agree that the global size currently exceeds seven billion and is increasing (USCB, 2016). Although population size is increasing steadily, the growth rate (change/time) has been slowing down since the late 1980s, with many projections predicting the global population will reach zero growth during the mid-late 21st century.

Understanding the human population and its historic and projected growth is essential for all students to become informed citizens. The global human population size has been a cause for concern since *An Essay on the Principle of Population* was published in the 18th century (Malthus, 1798). At the time, the global population was roughly one billion, and Thomas Malthus predicted a linear increase of one billion people every 25 years. Malthus was especially concerned that populations exceeding their available resources would be subject to famines and infectious disease. In the 20th century, Paul Ehrlich published *The Population Bomb*, which warned that overpopulation would lead to a global food security crisis and harm global ecosystems (Ehrlich, 1968).

Currently, global population size remains a concern. Global water security is a major challenge, with the majority (ca. five billion people) of the global population living in areas where water security is threatened (Vörösmarty et al., 2010). In developing nations, where populations grow most rapidly, nearly 800 million people face food insecurity (FAO et al., 2015). As development has occurred the last two decades, food insecurity has decreased globally and shifted to different regions. Since development increases individual ecological footprints and resource use (EEA, 2015), development and a growing population act in concert to create "ecological deficits." A population that continues to grow will contribute to and experience the negative components of global change such as climate change, invasive species, and catastrophic habitat loss.

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Demographic data at the local, national, and global levels are readily available to educators. Demographic data are useful for understanding past and current population dynamics, and for predicting what will happen to humans and the environment in the future. Moreover, since quantitative

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literacy is often lacking in biology students (AAAS, 2009), demographic data offer several opportunities to analyze and chart data to draw conclusions.

Here, I describe two exercises that explore how human population and population growth change over time. Both exercises utilize data found on webpages maintained by the United States Census Bureau, which tracks both U.S. and international population sizes. These exercises are shared so they can be used to supplement instruction in course units covering topics such as population growth and dynamics or human populations and sustainable resource use. They are appropriate for use in either high school or college biology or environmental science courses. I will provide both instructions on how to complete these exercises and my experiences using them in an introductory college biology course.

Learning Goals

These two activities align in several ways with the three dimensions of science learning defined by the Next Generation Science Standards (NGSS, 2016). By modeling dynamic changes with real human population data, students engage in the scientific practices of defining problems, developing models, and analyzing data. Upon completing these exercises, students should be able to

- extract information from online databases,
- show competency in spreadsheet software applications and formulas,
- graph linear trends, and
- calculate growth rates over different time periods.

Because population size is so dynamic, students explore crosscutting concepts such as quantity, stability, and change. Upon completing these exercises, students should be able to

- discuss factors that causes differences in human population growth rates,
- explain how and why human population growth rates have changed during the 20th century,
- estimate differences in population sizes at different growth rates, and
- predict population sizes at the end of different time periods.

Lastly, by encouraging a discussion of the effects of overpopulation, these exercises address the interdisciplinary core ideas of ecology, Earth, and human activity. Upon completing these exercises, students should be able to

- describe how population size influences resource use and availability, and
- connect population size to global change.

○ Exercises

Each of these two exercises is designed to be completed in a 50-minute class period, including introductions. Instructors should inform students ahead of time to bring computers with spreadsheet software (e.g., Microsoft Excel). Depending on the abilities of the students, instructors should plan on demonstrations of how to use spreadsheet software to make graphs; I teach them how to make line charts showing 5 percent growth in advance. In addition, I begin with a discussion of local population sizes and what factors (e.g., economic growth) influence them.

Exercise 1: Population Clocks

Students access the U.S. Census Bureau Population Clock webpage at http://www.census.gov/popclock/. This page shows the size of both the U.S. and world populations as constantly turning "odometers." The U.S. Clock turns relatively slowly, whereas the World Clock turns rapidly. Population clocks will be used to calculate birth rates, and birth rates can be applied to determine the population size at a predetermined date (e.g., the end of the year).

The U.S. population clock shows four components of change and their change per unit time immediately below the clock (Table 1). These components are dynamic and change 1 or 2 times a year. The first three components are needed to calculate the rate of change (people/unit time) (see Table 2 for instructions). Once students calculate the rate of change, they can multiply that times a specified number of units of time (e.g., days) to determine how much population has changed over the time interval being considered (e.g., from the date of the activity until the end of the year). The population change can be added to the current population to predict a future population.

The global population clock can be used to estimate a future global population size (see Table 2); however, the four components of change are not displayed. Net gains must be estimated indirectly by watching the clock turn.

Best practices. Instructors should explain each component of the U.S. Clock in advance. For instance, they may not realize that "net migrants" is calculated as the number of emigrants subtracted from the number of immigrants. Students should also be reminded to add the current population to the change to predict a future population; if not, they tend to mistakenly equate change in population with predicted future population.

The World Clock spins too rapidly to attempt to count along with it. Instead, students should wait until the clock reaches to the nearest hundred, then start a stopwatch.

The World Population Clock presents students with an opportunity to calculate annual growth (78.84 million people/year). Students can also calculate the current annual percent growth by dividing the yearly growth by the population size (1.08% increase in 2015, calculated in this way).

Exercise 2: Historical Data

This exercise allows students to make charts to visualize how population sizes would be different today if the historical percent growth remained constant. This exercise can be used with either U.S. historical data (http://www.census.gov/popest/data/national/totals/pre-1980/tables/popclockest.txt) or global historical data

Table 1. The components of population change displayed on the U.S. Census Bureau's U.S. Population Clock as of June 2016. These values are used for the calculations shown in Table 2.

Component	Time (s)
One birth	8
One death	13
One net (immigrants – emigrants) international migrant	28
Net gain of one person	13

Table 2. Steps for completing Exercise 1, and values generated using data available June 2016.

United States Population
1. Calculate the number of births per day: $\frac{\text{one birth}}{8\text{ sec}} \bullet \frac{60\text{ sec}}{1\text{ min}} \bullet \frac{60\text{ min}}{1\text{ hr}} \bullet \frac{24\text{ hr}}{1\text{ day}} = \frac{10,800\text{ births}}{1\text{day}}$ (Eq.1)
2. Calculate the number of net migrants per day: $\frac{\text{one migrant}}{28\text{ sec}} \bullet \frac{60\text{ sec}}{1\text{ min}} \bullet \frac{60\text{ min}}{1\text{ hr}} \bullet \frac{24\text{ hr}}{1\text{ day}} = \frac{3.086\text{ migrants}}{1\text{day}}$ (Eq.2)
3. Calculate the gross increase per day by adding the number of births plus net migrants: $10,800\text{ births} + 3,086\text{ migrants} = 13,886\,\frac{\text{people}}{\text{day}}$ (Eq.3)
4. Calculate the number of deaths per one day: $\frac{\text{one death}}{13\text{ sec}} \bullet \frac{60\text{ sec}}{1\text{ min}} \bullet \frac{60\text{ min}}{1\text{ hr}} \bullet \frac{24\text{ hr}}{1\text{ day}} = \frac{6,647\text{ deaths}}{1\text{day}}$ (Eq.4)
5. Subtract the number of deaths from the gross increase to get the net increase per day: $13,886 - 6,647 = 7,239\,\frac{\text{people}}{\text{day}}$ (Eq.5)
6. Use the net gain component to calculate net increase per day in a different way: $\frac{\text{one gain}}{12\text{ sec}} \bullet \frac{60\text{ sec}}{1\text{ min}} \bullet \frac{60\text{ min}}{1\text{ hr}} \bullet \frac{24\text{ hr}}{1\text{ day}} = \frac{7,200\text{ gain}}{1\text{day}}$ (Eq.6) Ideally students will recognize how the net gain component on the site was calculated. If rounding, the numbers obtained in steps 5 and 6 should be the same.
7. Extrapolate the total population at a future date by multiplying the net increase times the number of days in the selected time period (this is the change in population), and adding that to the current population. For example, if the selected time period is 50 days, then the change would be $\frac{7,239\text{ people}}{1\text{ day}} \bullet 50\text{ days} = 361,950\text{ people}$ (Eq.7) The extrapolated population would be the current population size plus 361,950.
World Population
1. Time the clock for 60 seconds and write down the population size at the beginning and end. The difference is the net gain per minute. As of June 2016, this number is 150 people/minute.
2. Use the net gain per minute to estimate the net gain per day: $\frac{150\text{ gained}}{1\text{ min}} \bullet \frac{60\text{ min}}{1\text{ hr}} \bullet \frac{24\text{ hr}}{1\text{ day}} = \frac{216,000\text{ gained}}{1\text{day}}$ (Eq.8)
3. Use the net gain per day to estimate the predicted population size at the end of a predetermined time period (e.g., the end of the year).

(http://www.census.gov/population/international/data/idb/worldpoptotal.php). As of 2016, the U.S. historical data are provided from 1900 to 1999, and the global historical data are provided from 1950 to 2050. The U.S. historical data are useful for analyzing 20th century trends such as the Great Depression and the post-war Baby Boom, but lack 21st century data and projections. Different questions, provided below, can be answered with each data set.

For both data sets, students look over the data and determine if trends in yearly percent change and year change are increasing or decreasing. Both are *decreasing*.

Students find in the datasets the highest annual percent changes last 100 years. For the United States, the highest is 2.05 percent (1950), and for the global set, the highest percent change is 2.224 percent (1963).

Percent changes can be compared to the highest annual gains in population in both data sets. In the United States, the greatest gain in population was in 1950 (3,083,287), the year with the highest annual percent growth. In the global data set, the greatest gain in population was 1980 (83,047,390). Students should here be able to recognize the relationship between percent growth and actual growth; a small percent growth (1.866% in 1980) in a larger total

A

	A	B	C	D
1	Year	Midyear Population	Annual Percent Growth	Annual Population Change
2	1963	3,209,827,882	0.0224	71,900,145
3	1964	3,281,728,027	0.0224	73,510,708
4	1965	3,355,238,734	0.0224	75,157,348
5	1966	3,430,396,082	0.0224	76,840,872
6	1967	3,507,236,954	0.0224	78,562,108
49	2010	9,092,038,446	0.0224	203,661,661
50	2011	9,295,700,107	0.0224	208,223,682
51	2012	9,503,923,789	0.0224	212,887,893
52	2013	9,716,811,682	0.0224	217,656,582
53	2014	9,934,468,264	0.0224	222,532,089
54	2015	10,157,000,353	0.0224	227,516,808

B

	A	B	C	D
1	Year	Midyear Population	Annual Percent Growth	Annual Population Change
2	1950	152,271,417	0.0205	3,121,564
3	1951	155,392,981	0.0205	3,185,556
4	1952	158,578,537	0.0205	3,250,860
5	1953	161,829,397	0.0205	3,317,503
6	1954	165,146,900	0.0205	3,385,511
7	1955	168,532,411	0.0205	3,454,914
62	2010	514,516,056	0.0205	10,547,579
63	2011	525,063,636	0.0205	10,763,805
64	2012	535,827,440	0.0205	10,984,463
65	2013	546,811,903	0.0205	11,209,644
66	2014	558,021,547	0.0205	11,439,442
67	2015	569,460,988	0.0205	11,673,950

Figure 1. Estimate of what the 2015 U.S. **(A)** and global **(B)** populations would be at midyear 2015 if both populations had continued to grow at their maximum rates since 1950 and 1963, respectively. Annual percent growths are entered as proportions so students can multiply columns B and C to calculate column D.

population means a greater change than a larger percent growth (2.224% in 1963) in a smaller population.

Students use the largest percent growth from their dataset to determine what the current population would be if that percent growth remained constant. This is best achieved with spreadsheet applications such as Microsoft Excel. Spreadsheet setup can vary; my setup is shown in Figure 1. In this setup, data are typed into the first row, and calculated into subsequent rows by copying formulas. The annual change (Column D) is calculated by multiplying the population size (Column B) times the percent growth (Column C). Each year's population size is the annual change plus the previous year's population size. Data are then copied easily to the current year. Students can then visualize how percent growth influences population size by producing charts (line charts or scatterplots) (Figure 2).

Students can locate the population size for each year in the database, and add that variable to the chart as an additional data series. By doing so they can compare the actual historical population growth with their calculated population size.

Best practices. Have students read about and share reasons that growth rates reached maximum values when they did. For the United States, economic growth after World War II is a major factor (Colby & Ortman, 2014) in 1950, whereas economic growth, demographic transitions, and the Green Revolution are all potential factors in the global population growth in 1963.

Depending on ability level, students may not know how to use their spreadsheet application to multiply. Students may multiply the percent as a number rather than as a percent (i.e., multiply the population size by 2.05 rather than 2.05% [0.0205]). If they do this, their estimated population size will be *much* too large in just a few generations.

Depending on experience, students may or may not know how to make charts, and may not know to label axes and write legends. I evaluate students based largely on the readability of their charts, which includes axis labels.

Questions and Discussions

In Exercise 1, I always ask students if they predict the actual population will exceed or be less than the value they calculate. Interestingly,

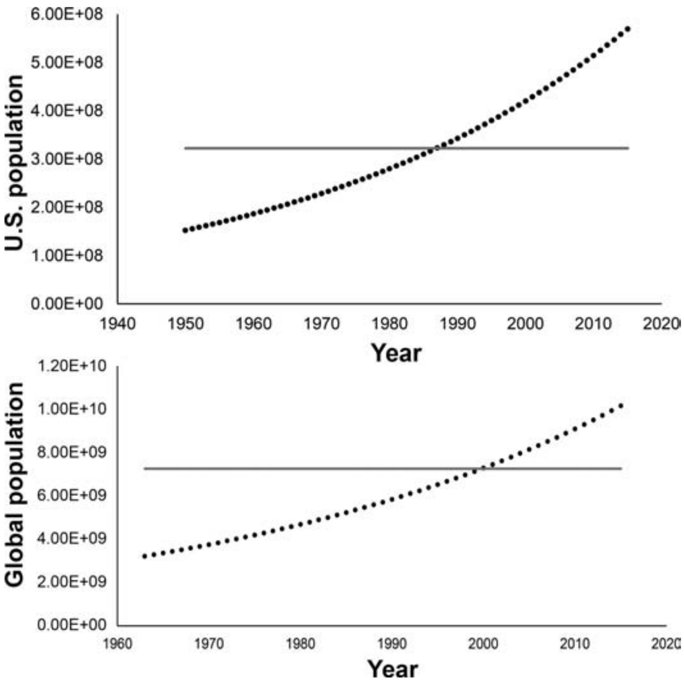

Figure 2. Scatterplot showing simulated population growth at maximum annual recorded percent growth. In both charts, calculated population size is represented by black dots for each year. Approximate 2015 population size is represented by the horizontal red line. **(A)** U.S. population growing at 2.05% since 1950. **(B)** Global population growing at 2.224% since 1963.

the majority of students who completed this exercise before seeing historical data for Exercise 2 predicted the actual population will be *larger*. A misconception that growth rate is still increasing seems to persist, and students can be informed during this exercise that growth rate has been decreasing for over two decades (see Exercise 2).

These exercises are natural for encouraging high-impact discussions on the global population, and the difference between the populations of nations that vary in developmental indices. Questions that can open discussion include:

1. Why be concerned about global population size?
2. Will global population size ever affect you? Explain your answer.
3. What are ways to reduce the impacts of a growing population?
4. What are some ethical issues the developed world must consider in regard to the developing world's population?
5. What is the importance of education, particularly in reproductive rights of women, to the global population? How is this different in the developed and developing world?

Comparing the dynamics of the U.S. and global populations world allows naturally for a discussion of ecological footprints and resource use. Americans have much larger ecological footprints than individuals living in other countries (ca.4 times that of Chinese individuals, ca.9 times that of Indian individuals [Ewing et al., 2010]), and are major users of resources. If developing nations were to use resources at the same rate as the United States, serious global deficiencies in water, food supply, and energy may result (Wackernagel et al., 2006).

○ Discussion

Population size and the rates of change are constantly changing. Students should recognize from these exercises how difficult it is to forecast population growth, because growth rate is dynamic and changes significantly in a short period of time. (The clock components have changed every semester I've done these exercises.) Students should recognize that growth may occur whether growth *rate* is increasing or decreasing. They should also note that the United States and world population dynamics are different, which should indicate to them that societies differ in demographics. Reasons for the differences can be discussed.

These exercises show growth only as a percent change and as a change over time. For upper-level courses, instructors can consider other factors such as the intrinsic rate of increase (r) of populations, and why that rate rarely applies to human populations. Density-dependent limiting agents such as infectious disease and resource availability can also be discussed. Graphing the population growth over time with a carrying capacity included (e.g, 10 billion, the median estimate of global human carrying capacity [Cohen, 1995]) can be a valuable addition to Exercise 2.

Completing these exercises has been a valuable experience for students. Students who have completed this exercise at my institution have reflected that they now recognize the importance of the global human population, and realize that there may be negative consequences as it continues to grow. They understand better the calculations that go into the famous images from their textbooks of population growth. In addition, they have reflected that this exercise has substantially improved their ability to use formulas and spreadsheet applications, produce readable graphics, and draw conclusions from large amounts of data.

Global human population is currently increasing, and it is vital that students recognize how populations have grown and continue to grow. Continued growth of global human populations can have major effects on all global systems, including those that supply humans with essential resources and services.

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