



EXPERIMENT

Population Ecology

Hands-On Labs, Inc.
Version 42-0281-00-02

Review the safety materials and wear goggles when working with chemicals. Read the entire exercise before you begin. Take time to organize the materials you will need and set aside a safe work space in which to complete the exercise.

Experiment Summary:

You will explore the field of population ecology and survey factors involved in the decline, expansion, and maintenance of a population. Simulated growth of a population will be modeled, graphed, and analyzed. You will use quantitative data from a cemetery population to study demographics.



Learning Objectives

Upon completion of this laboratory, you will be able to:

- Define species, population, and metapopulation.
- Differentiate between density-dependent and density-independent factors and describe how each can influence population size.
- Outline factors that influence carrying capacity and describe the potential consequences of overpopulation.
- Illustrate graphs of linear and exponential population growth.
- Describe how demography data may be used to calculate probability of mortality.
- Model population growth and determine if the growth was linear, exponential, or had no observable pattern.
- Determine constraints placed on a modeled population and draw conclusions about carrying capacity.
- Use birth and mortality data of a cemetery to investigate demography.
- Determine probability of death within a cohort.

Time Allocation: 3.5 hours

Note: This experiment suggests a field trip to a local cemetery for data collection. Please plan your time accordingly.



Materials

Student Supplied Materials

Quantity	Item Description
3	Sheets of paper (optional)
1	Pen or pencil
1	Access to a cemetery (optional)
1	Access to a printer (optional)

HOL Supplied Materials

Quantity	Item Description
1	Packs of dice, mini (100 pcs)
1	Cup, plastic, 9 oz., short
1	HOL Supplied Cemetery Data Supplemental Document

Note: To fully and accurately complete all lab exercises, you will need access to:

1. A computer to upload digital camera images.
2. Basic photo editing software such as Microsoft Word® or PowerPoint®, to add labels, leader lines, or text to digital photos.
3. Subject-specific textbook or appropriate reference resources from lecture content or other suggested resources.

Note: The packaging and/or materials in this LabPaq kit may differ slightly from that which is listed above. For an exact listing of materials, refer to the Contents List included in your LabPaq kit.

Background

Species and Populations

A **species** is a group of organisms that share many common characteristics and breed among themselves to produce fertile offspring. Individuals of a species that occupy a defined area at the same time are called a **population**. The habitat area of a population is often naturally enclosed within geographical boundaries, such as rivers or mountains. See Figure 1. In research studies about populations, scientists often define artificial boundaries. For example, scientists may investigate the population within a county or state boundary.



Figure 1. Small population of water lilies (family Nymphaeaceae) inhabiting a pond. © yuriy kulik

When suitable habitat is patchy or fragmented, populations can be spatially isolated, but members of the population can have some level of interaction with one another. When this occurs, the interacting populations are referred to as a metapopulation. An example of a species that is often found as a metapopulation is the desert bighorn sheep (*Ovis canadensis*). See Figure 2. The bighorn sheep occupies steep slopes of mountains that are separated by flat lowlands. Although the lowlands are an unsuitable long-term habitat for the sheep, individuals and groups of sheep are able to travel through the lowlands to adjacent mountains, resulting in interaction among individuals of different but connected populations.





Figure 2. Bighorn sheep. © Shane W. Thompson

Population Density

Biologists who study population ecology often investigate population size and factors involved in the decline, expansion, and maintenance of a population. Data about populations include the following:

- Mortality (death) and birth rates
- Movement of members into and out of the population (immigration and emigration)
- Number of individuals in a group, or **cohort** (for this experiment cohorts are the age classes of deceased individuals)
- Spatial distribution of species
- Population density (the number of individuals per unit area)

Factors related to the density of a population, called **density-dependent factors**, affect population growth by reducing or increasing the population size. For example, the ability to acquire a mate is a density-dependent factor. When population density is great, competition for mates increases. Members of the population may spend more energy competing for mates than actually mating, and the population size can subsequently decrease due to reduced births. On the other hand, when population density is optimal, competition may be relatively low and mating opportunities may be high, resulting in growth of the population. Other density-dependent factors include resource availability, predation rates, and disease transmission. **Density-independent factors** influence population growth but are not dependent on population density. Consider how the population density of trees may be affected by weather patterns and wildfires.

Growth rates can follow various patterns, as shown in Figure 3. When resources are unlimited, a population's growth rate can be exponential. Although the graph of exponential growth illustrates a potentially great increase in population size, no population can grow indefinitely. In nature, members of the population will eventually consume available resources, and the population size will ultimately plateau or decline due to density-dependent factors.

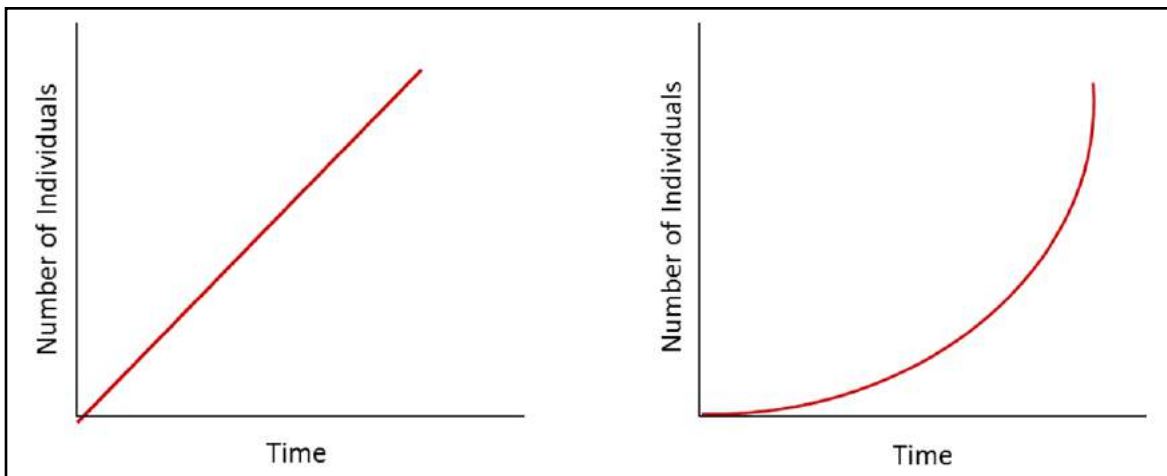


Figure 3. Population growth patterns. **A.** Linear. **B.** Exponential.

Every natural area has a **carrying capacity**, a decided number of individuals that can be supported given the area's limited resources. Carrying capacity is influenced not only by the number of members of a single population, but also members of competing populations. Furthermore, a given population may act as a resource for another population; for example, voles are a food resource for owls. Carrying capacities are in constant flux, as they are affected by both density-dependent and density-independent factors. In the event that overpopulation occurs and the carrying capacity is exceeded, a population collapse can occur; whereby the population size decreases dramatically. When a population completely collapses and no members remain, the population is locally extinct, or **extirpated**.

Human Populations

A subset of population ecology, **demography**, is the study of human populations. Cemeteries are an excellent place to study demography as they provide data on both the birth and death dates of individuals of a local population. This information can be used in turn to determine the probability of death and survival at different ages in a population. Table 1 is an example analysis of mortality. To generate the table, the number of individuals that died in each cohort (based on age class) must be determined. For example, the first cohort listed in Table 1 includes individuals that died from age one to nine. From this information, probability of mortality can be calculated. According to Table 1 there is a 15% probability of death in this specific population, between ages one and nine. Closely study the table descriptions provided below.

Table 1. Cemetery Demography Data.

Cohort (X)	Number of deaths (D)	Frequency of population in cohort (d)	Frequency of survivorship entering the cohort (I)	Probability of death within a cohort (Q)
1-9	24	0.15	1.00	0.15
10-19	20	0.13	0.85	0.15
20-29	5	0.03	0.73	0.04
30-39	10	0.06	0.69	0.09
40-49	16	0.10	0.63	0.16
50-59	40	0.25	0.53	0.47
60-69	35	0.22	0.28	0.78
70+	10	0.06	0.06	1.00

Table Description:

- Cohort (X) - The age intervals of deceased individuals
- Number of deaths (D) - The number of individuals that died in each cohort
- Frequency of population in cohort (d) - The portion of the population that died in each cohort, $d = D / \text{Total Population Size}$
- Frequency of survivorship entering the cohort (I) - The portion of the population that enters the cohort, $I_{\text{cohort2}} = I_{\text{cohort1}} - d_{\text{cohort1}}$
- Probability of death within a cohort (Q) - The probability that any given individual will die within a cohort, $Q = d / I$

Exercise 1: Modeling Population Growth

In this exercise, you will use dice to model population growth. Each die will represent an individual; new individuals will be born, and individuals will also die. You will track the entire population until the population density (number of individuals) reaches 100.

1. Before you begin to model population growth, examine the rules listed below and shown in Figure 4.

Rules

- Each die represents 1 individual of the population.
- You will start with 4 individuals.
- You will roll the dice to investigate births and deaths of the population.
- The number of dots on each die will represent a birth, a death, or neither birth nor death.
 - Birth = 1, 4
 - Death = 6
 - Neither = 2, 3, 5

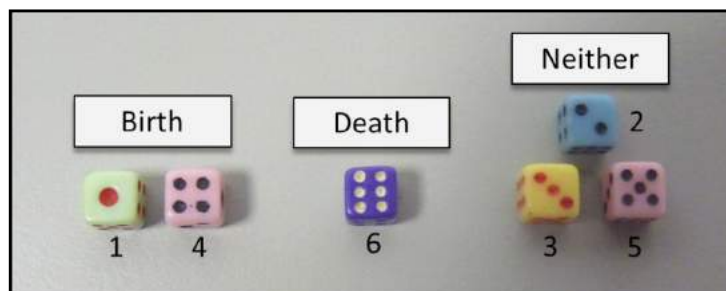


Figure 4. Rules of population growth activity.

2. Select 4 dice and place them in the cup. These dice represent the 4 individuals comprising generation 1, the initial population.

Note: The color of the dice does not matter.

3. In **Data Table 1** of your **Lab Report Assistant**, record the “Initial population size (N)” (for the first generation, the initial population size is 4).

- Cover the cup with your hand and shake the dice. Gently pour the dice onto a table or work surface.

Important Note: Pouring the dice out too quickly or too high from the work surface may result in lost dice. Take care not to inadvertently lose individuals.

- Determine the number of individuals that were born (any dice displaying numbers 1 and 4). Determine the number of individuals that died (any dice displaying number 6). See Figure 5.

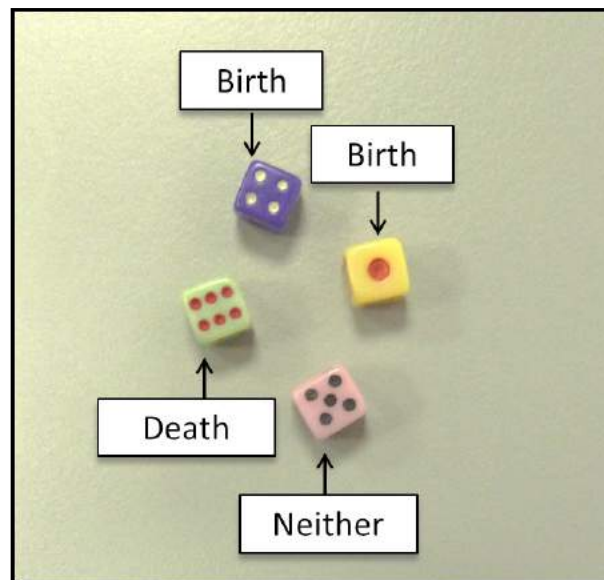


Figure 5. Example first generation: 2 individuals gave birth, and 1 individual died.

- Record the “Number of births (B)” and the “Number of deaths (D)” in **Data Table 1**.
- Remove any dead individuals. For example, in Figure 5 above, the dead individual should be removed from the population and returned to the bag.
- Add a die for each birth. For example, in Figure 5 above, 2 dice should be added to the population.
- Calculate the final population size and record the value in **Data Table 1**. Use the following equation:

$$\text{Final population size} = N + B - D$$

- Count the number of dice in your population to ensure that it equals the value recorded for “final population size” and return the dice to the cup.
- To obtain data for generation 2, repeat steps 3-10.

Note: Because you will be starting with a very small population, extinction is a possibility, but the odds are against it. If your population does go extinct, start again.

- Continue rolling the dice and recording data until your population size reaches a minimum of 100.

13. Once you have reached a population size of 100, calculate the change in population size for each generation. Record each value in **Data Table 1**. Use the following equation:

$$\text{Change in population size} = \text{Final population size} - \text{Initial population size}$$

14. Graph the initial population size for each generation. To do this, create a scatter plot with the generations on the independent axis (x-axis) and the initial population size on the dependent axis (y-axis). Consider whether the population growth you modeled showed a linear pattern, exponential pattern, or no pattern.
15. **Resize** the graph and insert it into **Data Table 2** of your **Lab Report Assistant**. Refer to the appendix entitled, “Resizing an Image” for guidance with resizing an image.
16. Graph the change in population size for each generation. To do this, create a bar graph with the generations on the independent axis (x-axis) and the change in population size on the dependent axis (y-axis). Consider whether changes in population size were greatest when the population was smaller or larger.
17. **Resize** the graph and insert it into **Data Table 3** of your **Lab Report Assistant**.

Questions

- A. How many generations did it take to reach a population size of 100?
- B. Consider the mode of reproduction modeled in your population. Would sexual reproduction or asexual reproduction likely be the cause of a birth? Are individuals of the species likely or unlikely to have separate male and female sexes?
- C. Did the modeled population exhibit linear growth, exponential growth, or no pattern? Use **Data Table 2** to support your answer.
- D. Were changes in population size greatest when the population was smaller or larger? Which generation exhibited the greatest change in size? Use **Data Table 3** to support your answer.
- E. What resource constraints were placed on the modeled population?
- F. Could the modeled population exhibit indefinite growth? If so, how? Is indefinite growth observed in nature? Explain why or why not.

Exercise 2: Investigating a Human Population

In this exercise, you will investigate demography of a human population. You will collect birth and death information from a cemetery and analyze trends in the population.

1. Research your local area to find a cemetery that you may visit for this exercise.

Note: If you are unable to access a cemetery, you may use the data provided in the “HOL Supplied Cemetery Data” Supplemental Document. If you choose to do this, skip to step 8.

2. Print a copy of **Data Table 4** from your **Lab Report Assistant**, to bring with you to the cemetery. Travel to a cemetery during the day, ensure that conditions are safe and public access is permitted.
3. In **Data Table 4**, record the name, birth date and date of death for 80 deceased individuals. As you collect data, be sure to spread out within the full sampling area. Individuals of the same family or who died in shared years will often be grouped together, and the goal is to take a representative sample of all individuals in the population.
4. Record the cemetery name and location in **Data Table 4**.
5. Determine how old each person was when they died, and record your data in **Data Table 4**. Use the following equation:

$$\text{Age at death} = \text{Birth year} - \text{Death year}$$

6. Investigate the first names of each individual and record the sex (M for male; F for female) in **Data Table 4**. If the name is gender-neutral, such as Jean, Lynn, or Pat, you may leave the area blank. Ensure that any data you recorded by hand is present in the **Lab Report Assistant** document that you report to your instructor.

Note: This concludes the outdoor portion of this exercise; the rest of Exercise 2 may be performed from home.

7. Record a summary of the population. Address each of the following questions, and record data in **Data Table 5** of your **Lab Report Assistant**.
 - What were the first and last birth years?
 - What were the first and last death years?
 - How many individuals died before 1950? How many died after 1950?
 - How many individuals are male and female?

8. In the next steps, you will calculate the probability of dying within a given cohort. As shown in **Data Table 6** of your **Lab Report Assistant**, cohorts are age classes. For example, cohort 1 includes individuals that died between the ages of 1 and 9; cohort 2 includes individuals who died between the ages of 10 and 19. Examine **Data Table 6** and study the following descriptions for each column heading:
- **Cohort (X)** - The age intervals of deceased individuals.
 - **Number of Deaths (D)** - The number of individuals that died in each cohort.
 - **Frequency of Population in Cohort (d)** - The portion of the population that died in each cohort.
 - **Frequency of Survivorship Entering the Cohort (I)** - The portion of the population that enters the cohort.
 - **Probability of Death within a Cohort (Q)** - The probability that any given individual will die within a cohort.
9. Count the number of people who died in each cohort (age interval). Record your data under “Number of deaths (D)” in **Data Table 6**.
10. Calculate the “Frequency of population in cohort (d).” Record each value as a number with two decimal places. Use the following equation:

$$d = D / \text{Total Population Size}$$

*Note: “Frequency of survivorship of cohort (I)” is based on entry into the cohort. Thus, the first cohort listed will always have a value of 1.00 because 100% of the population was born, entering into the cohort. A value of 1.00 has been entered for cohort # 1 in **Data Table 6**. With each subsequent cohort, values of “I” will decrease.*

11. Calculate the “Frequency of survivorship of cohort (I)” for cohort # 2. Record each value as a number with 2 decimal places. Use the following equation:

$$I_{\text{cohort2}} = I_{\text{cohort1}} - d_{\text{cohort1}}$$

12. Calculate the “Frequency of survivorship of cohort (I)” for each of the remaining cohorts. For example, “Frequency of survivorship of cohort (I)” for cohort 3 will be calculated as:

$$I_{\text{cohort3}} = I_{\text{cohort2}} - d_{\text{cohort2}}$$

*Note: The final recorded “I” in **Data Table 6** should be equivalent or very close to the final recorded “d.”*

13. Calculate the “Probability of death (Q).” Record each value as a number with 2 decimal places. Use the following equation:

$$Q = d / I$$

Note: The probability of death is a frequency and may be interpreted as a percentage. For example, if $Q=0.30$ for cohort # 1, then there is a 30% probability that a given individual will die between the ages of 1 to 9.

Note: To find Q , use data within a single cohort: $Q_{\text{cohort1}} = d_{\text{cohort1}} / l_{\text{cohort1}}$

14. Create a bar graph of the probability of death within each cohort. Plot the cohort age interval (1-9, 10-19, etc.) on the independent axis (x-axis), and plot the probability of death on the dependent axis (y-axis).
15. Resize the graph and insert it into **Data Table 7** of your **Lab Report Assistant**.
16. When you are finished uploading photos and data into your **Lab Report Assistant**, save your file correctly and zip the file so you can send it to your instructor as a smaller file. Refer to the appendix entitled "Saving Correctly" and the appendix entitled "Zipping Files" for guidance with saving the **Lab Report Assistant** correctly and zipping the file.

Questions

- A. Which cohort had the greatest probability of death? Which had the least probability? Use the graph in **Data Table 7** to support your answer.
- B. Overall, does human mortality tend to be greatest at young ages or older ages?
- C. How many individuals were male, and how many were female? How many individuals were you unable to assign a gender to?
- D. Using the raw data in **Data Table 4**, calculate the average age at death for males and for females. What inferences can you make about male versus female age at death?
- E. If the government made significant cuts in social services, such as prenatal and infant care, how might your data be affected?

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Lab Report Assistant

This document is not meant to be a substitute for a formal laboratory report. The Lab Report Assistant is simply a summary of the experiment's questions, diagrams if needed, and data tables that should be addressed in a formal lab report. The intent is to facilitate students' writing of lab reports by providing this information in an editable file which can be sent to an instructor.

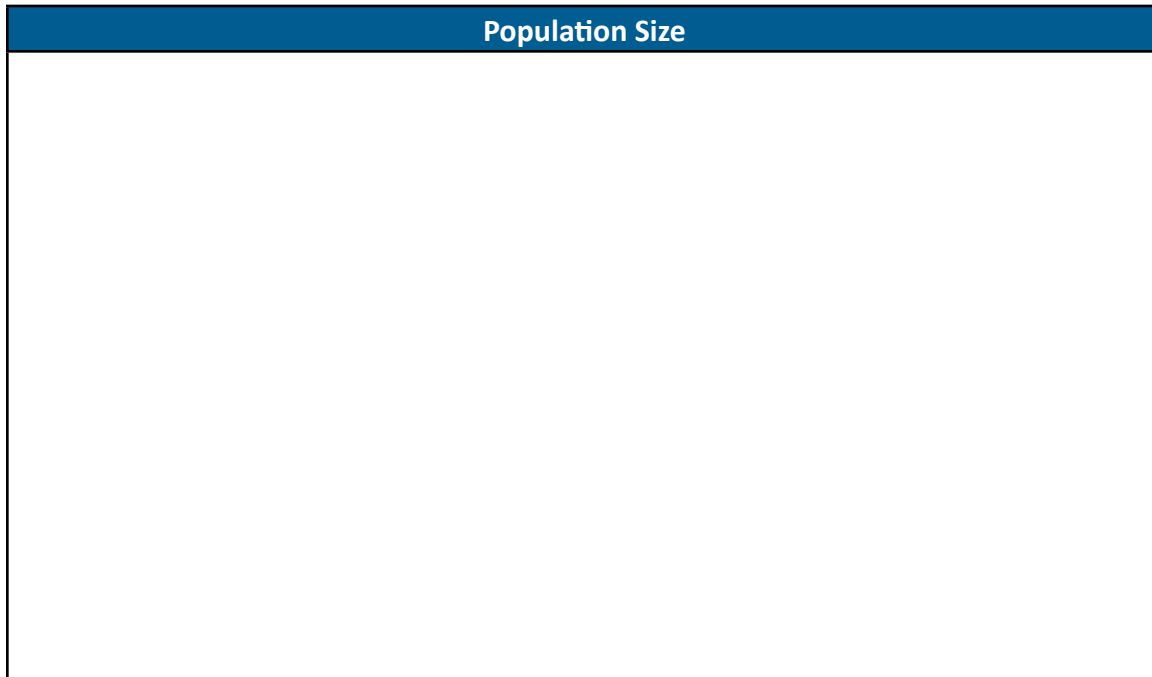
Exercise 1: Modeling Population Growth

See next page

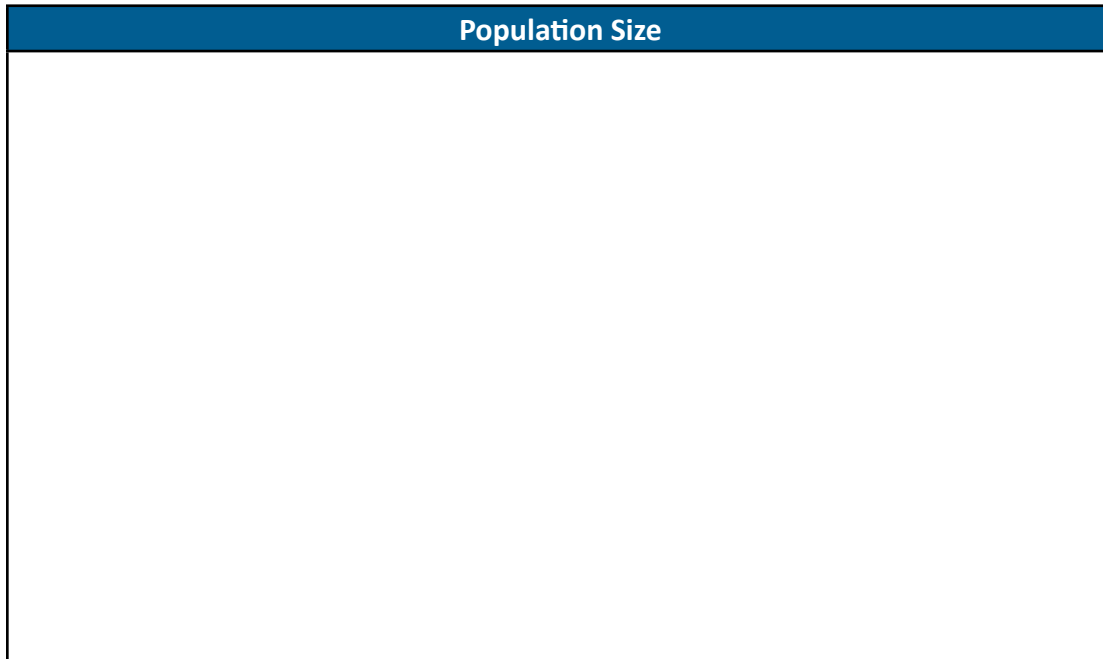
Data Table 1. Population Growth Model.

Generation	Initial Population Size (N)	Number of Births (B)	Number of Deaths (D)	Final Population Size (N + B - D)	Change in Population Size (Final - Initial)
1					
2					
3					
4					
5					
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Data Table 2. Population Size and Generations: Scatter Plot.



Data Table 3. Population Size and Generations: Bar Graph.



Questions

- A. How many generations did it take to reach a population size of 100?

- B. Consider the mode of reproduction modeled in your population. Would sexual reproduction or asexual reproduction likely be the cause of a birth? Are individuals of the species likely or unlikely to have separate male and female sexes?

- C. Did the modeled population exhibit linear growth, exponential growth, or no pattern? Use **Data Table 2** to support your answer.

- D. Were changes in population size greatest when the population was smaller or larger? Which generation exhibited the greatest change in size? Use **Data Table 3** to support your answer.

- E. What resource constraints were placed on the modeled population?

- F. Could the modeled population exhibit indefinite growth? If so, how? Is indefinite growth observed in nature? Explain why or why not.

Exercise 2: Investigating a Human Population

Data Table 4. Raw Data for Deceased Individuals.

Cemetery Name and Location:						
Individual	First Name	Last Name	Birth Year	Death Year	Age at Death	Sex (M/F)
1						
2						
3						
4						
5						
6						
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Data Table 5. Summary of Deceased Individuals.

Observations	Data
First birth year	
Last birth year	
First death year	
Last death year	
Number of individuals who died before 1950	
Number of individuals who died after 1950	
Number of males	
Number of females	

Data Table 6. Demography Data.

#	Cohort (X)	Number of Deaths (D)	Frequency of Population in Cohort (d)	Frequency of Survivorship Entering the Cohort (l)	Probability of Death within a Cohort (Q)
1	1-9			1.00	
2	10-19				
3	20-29				
4	30-39				
5	40-49				
6	50-59				
7	60-69				
8	70+				
	Total	80	1.00		

Data Table 7. Probability of Death within Each Cohort.

Probability of Death	

Questions

- A. Which cohort had the greatest probability of death? Which had the least probability? Use the graph in **Data Table 7** to support your answer.

- B. Overall, does human mortality tend to be greatest at young ages or older ages?

- C. How many individuals were male, and how many were female? How many individuals were you unable to assign a gender to?

- D. Using the raw data in **Data Table 4**, calculate the average age at death for males and for females. What inferences can you make about male versus female age at death?

- E. If the government made significant cuts in social services, such as prenatal and infant care, how might your data be affected?