Population Dynamics

Click & Learn
Student Worksheet

OVERVIEW
This worksheet complements the Population Dynamics Click & Learn.

PROCEDURE
Open the Click & Learn and read through the section “Why Build Population Models?” on the Population Dynamics tab. Proceed to the “Exponential” section. Follow the instructions below and answer the questions in the spaces provided.

PART 1: Exponential Models
A. Manipulating the exponential model
Read through the description of the exponential model and then proceed to the exponential model simulator. Click on the “How to Use” button.

1. What values does the *x*-axis represent?

2. What values does the *y*-axis represent?

3. Exit the “How to Use” page by clicking on the x button on the top right. Move the growth rate *r* slider to its lowest value of 0.1, then gradually increase it. What happens to the population size as you increase the growth rate?

4. Now place the growth rate at $r = 0.5$. (You can do this by adjusting the slider, or you can type in the value in the box next to the “*r* =” label and hit return.) How does the population growth vary if it starts from a small initial value ($N_0 = 5$ individuals) versus a larger initial value ($N_0 = 100$ individuals)?

5. Keep the growth rate at $r = 0.5$, and make $N_0 = 1000$ individuals. What is *N* when $t = 5$? To answer this question, you will have to rescale the graph so that you can see the higher values of *N*: Click on the gear icon and change the Max value of Pop. (N_0) to 15000. *N* = ____________

For questions 6 through 8, identify which parameters (large or small growth rate, large or small initial population size) will generate the following kind of graph:

6. A long period of almost no growth—the curve looks nearly flat.

7. A long period of slow but clearly accelerating growth—the curve starts to become steeper at the end.

8. Extremely rapid growth from the very beginning.

B. Investigating different scenarios

Waterbuck are a large antelope found in sub-Saharan Africa. Waterbuck populations in Gorongosa National Park in Mozambique are recovering after a devastating civil war. Scientists are trying to understand and predict changes in the size of waterbuck populations using models.

1. The initial values for the waterbuck population are as follows: $b = 0.67$, $d = 0.06$, $N_0 = 140$. Calculate the waterbuck population growth rate r.

2. Enter your calculated growth rate and initial population value into the exponential model simulator. Does this model predict that waterbuck population growth will ever slow down or decline?

3. So far, we've examined growth over 10 years ($t = 10$). Click on the gear icon and change the Max value of time to 100. Observe the population growth over the period of 25 years. Does this accurately reflect reality? Why or why not?

> **Limiting factors** are anything that constrains population growth, such as food or nesting space, and keeps populations from growing exponentially forever.

4. Think of two other possible limiting factors that could apply to waterbuck populations.

> A population without any limiting factors grows at its **biotic potential:** the maximum possible growth rate under ideal circumstances. Bacteria in a laboratory environment can briefly grow at their biotic potential, but otherwise few organisms have the opportunity to grow this fast.

5. Fill in the chart below with the population size (N) and rate of change of population (given by the slope, $\frac{dN}{dt}$) at each time, t, using the same parameters: $b = 0.67$, $d = 0.06$, $N_0 = 140$.

time	5	10	15	20	25
Population size ($N_{(t)}$)					
Slope ($\frac{dN}{dt}$)					

6. Describe how both the population size and the rate of change of population vary over time.

7. In an exponential model, the growth rate is controlled by the parameter r. Is the growth rate r the same at time t = 5 and time t = 20? Why or why not?

8. A decrease in the number of predators lowers the death rate of waterbuck to 0.04. How would this change the growth rate r?

9. How would this new growth rate influence the population size at time t = 20?

10. We've been defining r as the difference between the number of births and the number of deaths ($r = b - d$). However, movement of individuals into (**immigration**, i) and out of (**emigration**, e) an area can also change the growth rate. An updated r term would include all of these variables: $r = (b - d) + (i - e)$.

    How would the waterbuck population be different at time t = 20 if more waterbuck immigrated into the area? Use the values i = 0.25, e = 0, b = 0.67, d = 0.06, N_0 = 140.

PART 2: Logistic Models

Click on the "Logistic" button at the top and read through the description of the logistic model, then proceed to the logistic model simulator.

A. Manipulating the logistic model

The logistic model adds the concept of **carrying capacity, *k***. This is the maximum number of individuals that the community can support without exhausting resources.

1. Use default starting values for *r* (0.6) and N_0 (100). Select a value for *k* smaller than the N_0 value. What happens to the population over time?

2. Keep the same values for *r* and N_0. Now, select a value of *k* larger than the N_0 value. What happens to the population?

3. Describe a set of values for *N* and *k* that results in a slope that is almost zero. What is needed for this to happen?

4. Set the model with a value of *k* larger than N_0. What happens as you increase *r*?

5. Set the model with *k* = 1,000, *r* = 0.62, and N_0 = 10, and change the maximum value of *t* to 25. Create a table below showing the values for the population size and population growth rate (slope) values for different values of *t*.

6. Select *t* = 0, but keep all other settings the same as above. Click on the play button. What happens to the slope over time?

7. How is the result in the previous question different from your results with the exponential model?

B. Kudu scenarios

Kudu are an antelope species found in eastern and southern Africa. Male kudu have dramatically spiraled horns, which makes them a target of trophy hunters. Assume that the carrying capacity in a park is 100 kudu. Parameters: $k = 100$, $r = 0.26$, $N_0 = 10$.

1. At what time do kudu populations reach their carrying capacity? (You may need to change the max value of *t* and adjust the max value of *k* to optimize the graph display.)

2. What happens to the growth rate of a kudu population as it reaches its carrying capacity?

3. Assume a new plot of land is added to the park, increasing the carrying capacity to 250 kudu. How will the population size change?

4. This population started from only 10 individuals. How could small population sizes make populations vulnerable to extinction?

5. Reset the carrying capacity back to 100. Trophy hunters move into the area, leading to an increased death rate, which decreases the growth rate *r* to 0.15. How would this impact the population size? (Hint: Look at when the population reaches its carrying capacity.)

6. Although logistic models can be more realistic than exponential models, they still do not perfectly capture all aspects of population growth. Can you think of some additional details that impact population growth that these simple logistic models do not capture?

PART 3: Interpreting Data

A. Wildebeest and rinderpest

In the 1980s, wildebeest and other ungulates in the Serengeti were decimated after they became infected with rinderpest, a virus related to measles. Wildebeest populations began to recover when farmers started vaccinating domestic cattle, which were the source of the virus (Figure 1). Use the following population parameters: k = 1,245,000; r = 0.2717; N_0 = 534.

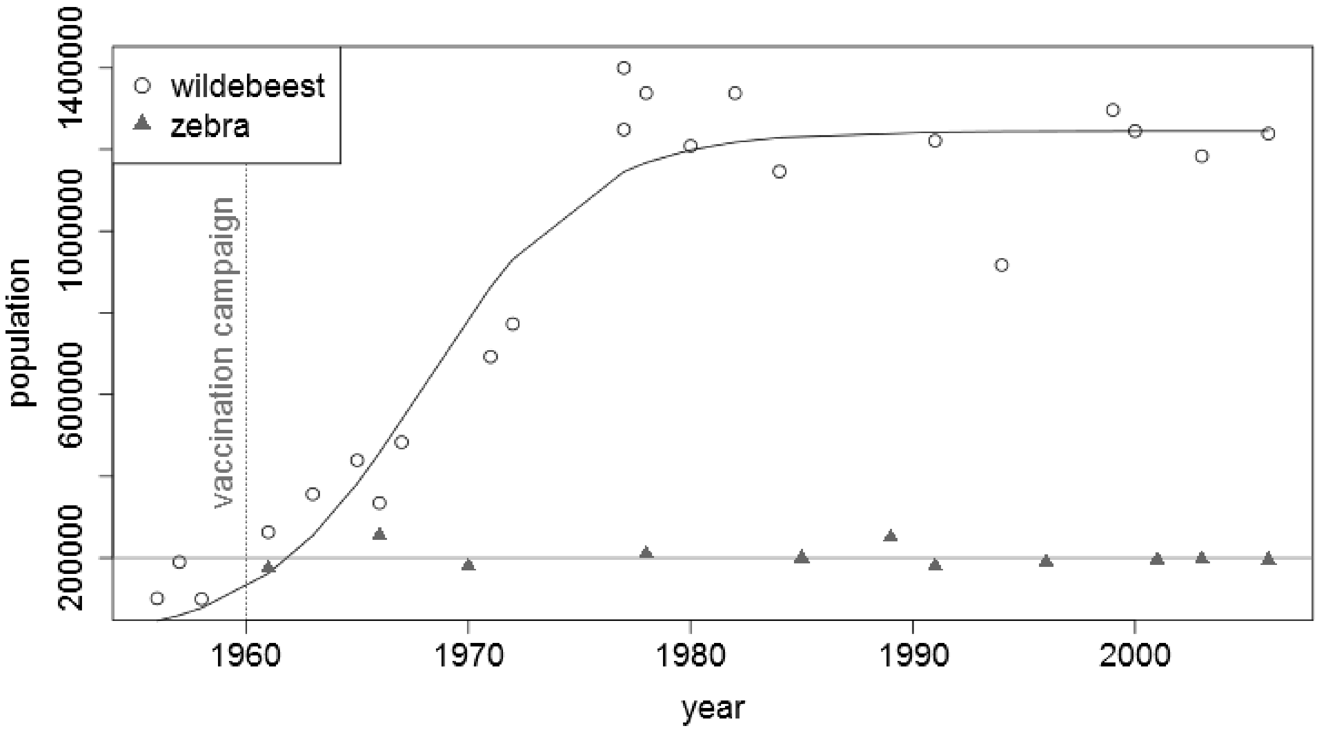

Figure 1. Wildebeest and zebra populations in the Serengeti from the 1950s to 2010.

1. What kind of population growth model would you use to represent wildebeest populations? Why?

2. Were wildebeest populations at their carrying capacity in 1965? Why or why not?

3. If the growth rate was r = 0.3, how would the wildebeest population recovery change?

4. What would happen if the carrying capacity increased to 2,500,000 wildebeest after adding more protected grazing land?

5. Zebra populations (triangles) stayed stable both during and after the rinderpest epidemic. What does this suggest about zebras' susceptibility to the rinderpest virus?

6. Does the rate of change of zebra populations ($\frac{dN}{dt}$) differ in the years 1985 and 2003? Use a logistic equation and parameter values: N_0 = 175,000; r = .01; k = 200,000.

7. How might zebra and wildebeest populations change if there was a wildfire?

B. Modeling human populations

1. Based on what you know about human population sizes over time, what kind of growth model do you think might fit human populations? Why?

2. Find a graph of human populations over time. Did this graph fit your prediction?

3. Can this growth trend continue?