**Population Growth Lab**

**OBJECTIVES**

* Model population growth exponentially and logistically
* Graph exponential and logistic curves
* Describe factors affecting different types of growth

**INTRODUCTION**

Populations that breed continuously exhibit two types of growth: exponential and logistic. Most populations will experience exponential growth at some point, especially when food supplies are abundant. However, exponential growth is typically kept in check with **density-dependent factors** which typically reduce the growth rate of populations as their population increases. Examples of density-dependent factors include predation, lack of food sources, lack of space, and disease. These density-dependent factors push populations into logistic growth in which populations reach a carrying capacity. When mathematically modeling logistic growth, the population appears to reach a finite value, but in reality, the population will fluctuate around the carrying capacity as environmental conditions change. **Density-independent factors** affect both exponential and logistic populations no matter the size of the population. Some examples include natural disasters such as hurricanes, tornadoes, and wildfires. Today, we will explore the mathematical models of exponential growth and logistic using Microsoft Excel. With these models, we can make predictions about population sizes of harmful bacteria, recovering populations of endangered species, and the impact of a growing human population.

**Submission Note:** You will be turning in a Microsoft Excel file; you do not need to copy and paste data tables or graphs into this worksheet.

**CASE STUDY**

This lab will explore logistic and exponential growth in a black rat population, which has a severe impact on farming in Southeast Asia. We will be watching various parts of the PBS Nova Documentary ‘Rat Attack’ on YouTube which focuses on Mizoram, a state in eastern India. To begin, navigate to the video: <https://www.youtube.com/watch?v=tSGxVx0uT8Y> and watch from the beginning to 2:29. Keep this video open as we will refer to different parts of the video during the lab.

These ‘rat attacks’ do not happen every year. Watch the video from 11:02 – 13:46 and answer the following questions.

1. How often do the rat plagues occur?
2. The rat plagues occur during mautam. What is mautam?

In order to calculate black rat growth over many generations, we need to figure out the per-capita growth rate (*r*) during normal conditions and during mautam. A **generation** is the average time between the birth of an organism and the birth of its offspring. To estimate, we will divide lifespan by the number of litters an individual has. We can figure out *r* by understanding the life history of black rats in these two periods, as seen in the table below.

1. Fill in the blanks in the life history table below using the clips from the video.

**Table 1:** Black rat life history table during a regular season and during mautam

|  |  |  |
| --- | --- | --- |
|  | **Normal Conditions** | **Mautam** |
| **Lifespan** | 12 months |
| **Number of litters during lifetime** | \_\_\_\_\_\_\_*(can find this at 49:15-50:36)* | \_\_\_\_\_\_\_*(can find this at 49:15-50:36)* |
| **Length of one generation** | \_\_\_\_\_\_\_*(calculate this using the lifespan and number of litters)* | \_\_\_\_\_\_\_*(calculate this using the lifespan and number of litters)* |
| **Number of offspring per litter** | \_\_\_\_\_\_\_*(can find this at 31:49-33:15, how many pups were in this burrow?)* | \_\_\_\_\_\_\_*(can find this at 31:49-33:15, how many pups were in this burrow?)* |
| **Percentage of surviving offspring per litter** | <50%(*learn why at 16:41-17:37)* | \_\_\_\_\_\_\_*(can find this at 16:41-17:37)* |
| **Number of surviving offspring per litter** | 3 | \_\_\_\_\_\_\_ |

In another part of the video, the scientist estimates that there are about 100 rats outside of a local farm. Assume there are 50 males and 50 females (forming 50 mating pairs) that can all reproduce and are evenly distributed in ages. Use the life history data in the table above to answer the following questions. Be sure to show all work.

1. a. During **normal conditions**, how many offspring will be born (*B*) in one generation?

b. What is the per-capita birth rate (*b*)?

1. a. During **normal conditions**, how many total rats (adults and offspring) will have died (*D*) in one generation? Assume 50% of adult rats die, and use Table 1 to determine the number of non-surviving offspring. *(Since the starting population of rats is equally distributed in age and the 6-month generation is 50% of their 1-year lifespan, we can assume about 50% of the adult rats will have died in one generation.)*

b. What is the per-capita death rate (*d*)?

1. Using the information from questions 4 and 5, calculate the per-capita growth rate (*r*) for rats during **normal conditions**.
2. a. During a **mautam** year, how many offspring will be born (*B*) in one generation?

b. What is the per-capita birth rate (*b*)?

1. a. During a **mautam** year, how many total rats (adults and offspring) will have died (*D*) in one generation? Assume 25% of adult rats die, and use Table 1 to determine the number of non-surviving offspring. *(Since the starting population of rats is equally distributed in age and the 3-month generation is 25% of their 1-year lifespan, we can assume about 25% of the adult rats will have died in one generation.)*

b. What is the per-capita death rate (*d*)?

1. Using the information from questions 7 and 8, calculate the per-capita growth rate (*r*) for rats during a mautam season.

As you may have noticed, the per-capita growth rate (*r*) is different for these two time periods. *r* can fluctuate based on environmental conditions, though in exponential and logistic growth modeling, *r* remains constant for the entirety of the model. One way we can make a distinction between different values for *r* in a single population is denoting *r* as *rmax*. This metric, *rmax*, is the maximum per-capita growth rate that a population can undergo. This assumes the maximum number of offspring are being created, maximum offspring survival, and maximum adult survival the population can sustain given unlimited resources.

**LOGISTIC GROWTH DURING THE REGULAR SEASON (**$\frac{ΔN}{ΔT}=rN \frac{(K -N)}{K}$**)**

Most of the time in southeast Asia is *not* in mautam. Numerous species of rats live in the area, but farmers and locals do not need to worry about their population growth wreaking havoc on their livelihoods. The black rats and other species live in an ecosystem balance. Let’s imagine that near a rice farm there are 100 black rats and see how their population changes ($\frac{ΔN}{ΔT}$) over 10 generations if the carrying capacity (K) is 1,000.

1. Open the Excel data template and open the worksheet called "Logistic - Normal". Using the data given above (starting population size, *N*, and carrying capacity, *K*) and the *r* that you calculated earlier, create a data table and use formulas to determine the black rat population size outside this farm over 10 generations.
	* All you need are simple equations to make this table. Refer back to your notes on what you need to calculate and use formulas to do this. DO NOT CALCULATE ROW BY ROW.
2. In this worksheet, create a scientific graph of the population growth over time.
3. In one or two sentences describe the change in population size and growth rate over time. What is the population size at the beginning of the 10th generation?
4. Although you plotted 10 generations, how much actual time does this cover? Show your work.
5. In the Excel template, select the tab “Exploring the Equation”. Follow the instructions on the excel worksheet.
6. As N approaches K, what happens to (K-N)/K?
7. Explain your answer for A using biological terms such as carrying capacity, population size and population growth.
8. How does (K-N)/K affect ΔN/ΔT?
9. Explain your answer for C using biological terms such as carrying capacity, population size and population growth.
10. Go back to the “Logistic - Normal” tab in the Excel file. Reexamine the rat population growth in your logistic growth table and graph. At which point(s) are ΔN/ΔT the largest? The smallest? Explain.

**EXPONENTIAL GROWTH DURING MAUTAM (**$ \frac{ΔN}{ΔT}=rN$**)**

Mautam can be a catastrophic time for communities in southeast Asia. The devastation the black rat population can do can cause widespread crop failure, leading to less food and the need for humanitarian intervention. Understanding how these black rat populations grow can help farmers plan the timing of their crops to be harvested just before the rat population explodes to prevent losing their crops.

Similar to logistic growth, we will calculate exponential growth starting with 100 rats and the *rma*x calculated earlier in this activity.

1. In the Excel file you used above, open the worksheet called "Exponential - Mautam”. Using the data given above (starting population size) and the *rmax* that you calculated earlier, create a data table and use formulas to determine the black rat population size outside this farm over 10 generations.
2. In this worksheet, create a scientific graph of the population growth over time.
3. In one or two sentences describe the change in population size and growth rate over time. What is the population size at the beginning of the 10th generation?
4. Although you plotted 10 generations, how much actual time does this cover? Show your work.
5. Specifically, how could farmers use the information from this growth model to make decisions related to their livelihood?
6. This black rat population likely wouldn’t keep growing at this rate for 10+ generations. Describe why not and what would eventually happen.

**COMPARING POPULATIONS**

1. There are two reasons why we cannot graph both of these growth curves on the same graph. Describe one reason. *\*Hint: look at the axes\**
2. In reviewing the growth curves, data, and graphs, what do you notice? If you were a farmer in an area plagued by black rats, what would your thoughts and feelings be from seeing this data?
3. This case study focused on rice production and the impact of black rats, but these growth models can be used in many contexts. Describe another real-life scenario where information from either or both the logistic and exponential model could help with a problem.