Name \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Date \_\_\_\_\_\_\_\_\_\_\_\_\_



**LAB EXERCISE:**

Population Growth

**Introduction**

Why do we sometimes hear about swarms of rats or locusts, but *never* swarms of elephants or tigers? What is it about rats that allows them to “breed like rabbits”, but never rhinoceroses?

Could the answer just be as simple as: “rats have more babies than rhinoceroses”? 

*Well, yes and no.*

In an attempt to understand the disparity in the swarming nature of some species versus others, we need to understand the **life history traits** of those species. These generally include relevant details like:

* The **size** of the animals at birth
* The **age** at which offspring reach sexual maturity
* The **number** **of offspring** a female can have at a time
* The **number of times** a female can reproduce

Let’s come back to how these characteristics affect population “explosions” and first attempt to understand the basics of **population growth**. To do so, there are a few simple factors that influence the size of a population:

**Births** add new individuals to a population. The absolute (total) number of births per generations ***(B)*** doesn’t tell you a lot about a population. If you were told that a population had 100 births in a year, is that a *large* or a *small* number of births? The answer depends on the size of the population.

Therefore population ecologists might prefer to use the **“per-capita” birthrate *(b)****.* This is roughly equal to the total number of births *(B*) divided by the size of the population ***(N)***.

Therefore, the **birthrate** = ***b*** =***B/N***

1. If a population containing 500 rats saw 100 babies born in a generation, what would the absolute number of births ***(B)*** be, and what would the birthrate ***(b)*** be? 

***B* =**

***b* =**

1. Which one of these tells you **more** about the growth of the rat population?

**Deaths** remove individuals from a population, thereby decreasing the size of the population. The absolute (total) number of deaths per generations ***(D)*** also doesn’t tell you a lot about a population. A large population could have many deaths, but still be rapidly growing. Alternatively a small population with very few deaths could still be shrinking.

The **“per-capita” death rate *(d)*** is equal to the total number of deaths *(D*) divided by the size of the population *(N)*.

Therefore, the **death rate** = ***d*** =***D/N***

1. If our population of 500 rats from the previous question lost 75 rats to disease and predation that generation, what would the absolute number of deaths ***(D)*** be, and what would the death rate ***(d)*** be?

***D* =**

***d* =**

1. Using what you know from the previous three questions, is the rat population **growing** or **shrinking**? How did you figure this out?

The per-capita birthrate and death rate can be used to calculate an extremely important tool for demographers: the **per-capita growth rate *(r)*** of the population.

Functionally, this **growth rate *(r)*** is equal to the difference between the birthrate and the death rate.

Therefore, the **per-capita growth rate** = ***r*** = *(****b – d)***

1. Calculate the *per-capita* **growth rate *(r)*** for the rat population above.
2. What does **“per-capita”** mean? (Feel free to use the internet if needed)

The **total** **number of individuals added to a population *(***$\frac{ΔN}{ΔT}$***)*** depends on the rate of growth *(r)* and the current size of the population *(N).* Delta (Δ) is interpreted as the change in a variable. *N* is the population size and *T* is the amount of time. Therefore, we can interpret $\frac{ΔN}{ΔT}$ as the change in a population over time.

Functionally, the *per-capita* rate of increase is converted to the actual increase by multiplying it by the number of individuals in the population.

Mathematically, the **total number of individuals added** = $\frac{ΔN}{ΔT}$ =***r × N***

|  |  |
| --- | --- |
| **Variable** | **Definition** |
| $$\frac{ΔN}{ΔT}$$ | Change in a population (Δ*N*) over time (Δ*T*). Expressed as a number of individuals |
| *r* | Population growth rate. Solved by the birth rate minus the death rate. |
| *N* | Population size expressed as a number of individuals. This number will increase with each generation. |

1. Use the per capita rate of increase you calculated in question 5 and multiply that by the size of the population from question 3. What is the **actual number of individuals added** to the population that generation?

**Kinds of Population Growth:** Exponential Growth

All populations that breed continuously can experience two types of population growth: exponential and logistic.

When resources like food are plentiful, populations can enjoy exponential growth.

What happens when a population grows at a constant rate? To figure this out you will use the following information and plot the growth of a population over many generations. Most importantly, note that **the rate of growth (*r*) will not change**, but the size of the population (*N*) will change.

Take a **starting population size of 100**. Each generation, the population increases by 20% (**meaning the *per capita* rate of increase is 0.2**). Using the following graph, plot the size of the population over 20 generations (the starting population being generation 0). 

**BEFORE** you do any calculations, think for a moment what the growth of a population should look like if the rate of increase is **CONSTANT**. Sketch what you expect the graph to look like here.





*This value can be rounded to the nearest whole number*

|  |  |  |  |
| --- | --- | --- | --- |
| Generation  | Starting *N* | Rate of Growth | Number of Individuals Added  |
| 1 | 100 | 0.2 |  |
| 2 |  | 0.2 |  |
| 3 |  | 0.2 |  |
| 4 |  | 0.2 |  |
| 5 |  | 0.2 |  |
| 6 |  | 0.2 |  |
| 7 |  | 0.2 |  |
| 8 |  | 0.2 |  |
| 9 |  | 0.2 |  |
| 10 |  | 0.2 |  |
| 11 |  | 0.2 |  |
| 12 |  | 0.2 |  |
| 13 |  | 0.2 |  |
| 14 |  | 0.2 |  |
| 15 |  | 0.2 |  |
| 16 |  | 0.2 |  |
| 17 |  | 0.2 |  |
| 18 |  | 0.2 |  |
| 19 |  | 0.2 |  |
| 20 |  | 0.2 |  |

Use your data from the table to create a graph showing the growth of the population. *(This will give you a good idea of the scale for your graph)*

Population size

Generation

The population growth curve you graphed is an **exponential growth** curve.

1. If ***r*** was **constant** (0.2) for each generation, how did the graph turn into an exponential curve instead of a straight line?
2. What will keep a population from growing exponentially ***indefinitely***?

**Kinds of Population Growth:** Logistic Growth

Normally, we expect some **limiting resource** or outside force to slow the growth of a population, and therefore keep it from growing exponentially forever. This limitation could increase the death rate *(d)* with a rise in disease or predation, or could decrease the birth rate *(b)*as resources like food become scarce.

Regardless, eventually the rate of growth ***(r)*** will change. At that moment the population growth is, by definition, no longer exponential. Population growth that is slowing due to constraints in the environment is considered **logistic population growth**.

Why are there constraints in the environment? The environment can only support a finite number of individuals, be they mice, rabbits, humans, or bacteria. The **number of individuals that the environment can support** (without being depleted) is called the **carrying capacity** ***(K).***

The effect of the carrying capacity on the growth of a population is represented mathematically as:

 **Effect of carrying capacity on *r* =** $\frac{(K -N)}{K}$

The logistic growth of a population can therefore mathematically be calculated as the exponential growth multiplied by this carrying capacity limitation.

**Total number of individuals added (during logistic growth)** = $\frac{ΔN}{ΔT}=rN \frac{(K -N)}{K}$

|  |  |
| --- | --- |
| **Variable** | **Definition** |
| $$\frac{ΔN}{ΔT}$$ | Change in a population (Δ*N*) over time (Δ*T*). Expressed as a number of individuals |
| *r* | Population growth rate. Solved by the birth rate minus the death rate. |
| *N* | Population size expressed as a number of individuals. This number will increase with each generation. |
| *K* | The carrying capacity of the population, as given in a scenario. |
| $$\frac{(K -N)}{K}$$ | This term is the impact that the carrying capacity has on the growth of a population (and limits the exponential growth) |

How will this affect the growth of a population? You will again graph the growth of a population with a **starting population size of 100** and a **growth rate of 0.2**. However, this time you will factor in the carrying capacity of the environment ***(K)****.* If the environment **can only sustain a population of 300 rats**, how will this affect the growth of the population?

*Thoughts to consider before graphing:*

1. What should happen to the rate of growth *(r)* when the population reaches the carrying capacity *(K)*? Will *r* become a large number of a small number?
2. What do you think the graph will look like this time? 

Again, draw what you expect to see before calculating and graphing the population sizes.



1. Now go on to complete the calculations, fill in the following table, then use that table to create a growth curve for that population.

|  |  |  |  |
| --- | --- | --- | --- |
| Generation  | Starting *N* | Effect of *K* on *r* | Number of Individuals Added  |
| 1 | 100 |  |  |
| 2 |  |  |  |
| 3 |  |  |  |
| 4 |  |  |  |
| 5 |  |  |  |
| 6 |  |  |  |
| 7 |  |  |  |
| 8 |  |  |  |
| 9 |  |  |  |
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| 16 |  |  |  |
| 17 |  |  |  |
| 18 |  |  |  |
| 19 |  |  |  |
| 20 |  |  |  |



Population size

Generation

**Case Study**

This lab will explore both logistic and exponential growth of a population of black rats, which, during severe outbreaks, can have a serious effect on farming in Southeast Asia.

 



To begin, start the video and watch from the beginning to 2:29. Be sure to keep the video open as we will return to it to refer to different parts of the video throughout the lab.

Already we can see that the surging rat populations will have a negative effect on humans. What is the primary way in which these rats cause harm to humans living in eastern India?