Population Growth Rates

For YSP Volunteers: How to Run this Activity

Logistics

Number of Volunteers: 2 or 3 per 15 students
Amount of Set-up Time: 15 min
Amount of Running Time: 1.5 hours

Module Overview

This module focuses on teaching the ecology of population biology primarily teaching students about exponential and logistic growth rates. We use plants as our focal taxa for this activity. This module is essentially a 2 for 1. The first activity will be one that will need to be done over time. Therefore, if not visiting the school again we recommend not doing this one. The second activity is an exercise modeling population growth with the students.

Curriculum Links

Missouri Science Standards

4.1.B-a - Identify and explain the limiting factors (biotic and abiotic) that may affect the carrying capacity of a population within an ecosystem
2.1B-a - Make qualitative and quantitative observations using the appropriate senses, tools and equipment to gather data (e.g., microscopes, thermometers, analog and digital meters, computers, spring scales, balances, metric rulers, graduated cylinders)

Next Generation Science Standards

HS-LS2-1 - Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.
HS-LS2-2 - Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.

Goals

1. Know the difference between logistic and exponential growth rates
2. Understand what makes a species successful
3. Predict how density-dependent factors control population growth

Materials

- Grass field or at least a 30-m field
- Good weather
  - If you don't have good weather instead of running you can request the students to walk around in a large classroom
- Clipboard and lesson plan for recording data
- Seeds (preferably herbs) 50 seeds per group
- 5 pots
- Permanent Markers
- Pencil
- Water
- Watering can
- Grow light kit

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- Soil
- Tape

What to Expect
The students will love to do this activity but remember to make sure to give them the rules.

Resources
- https://www.khanacademy.org/science/biology/ecology/population-growth-and-regulation/a/exponential-logistic-growth
- http://www.ngsslifescience.com/science.php?/biology/lessonplans/C415/

Introduction
Ecosystems are sets of living organisms (plants, animals, and microorganisms) all interacting together with the environment in which they live (soil, climate, water and light). They can vary in size. They can be as small as a puddle or as large as the Earth itself. Any group of living and nonliving things interacting with each other can be considered an ecosystem. A **population** is a group of the same species within an ecosystem. A **community** is all species within an ecosystem. The **habitat** is the environment in which the species resides.

In theory, any kind of organism on Earth could take over by simply reproducing. However, when you look around you notice that there isn't a single species that has dominated this planet. Why is that? All living organisms need specific resources, such as nutrients and suitable environments in order to survive and reproduce. These resources are limited and a population size can only reach a size that match the availability of resources in its local environment.

The general equation for population growth rate (change in numbers of individuals in a population over time):

$$\frac{dN}{dT} = rN$$

In this equation, *dN/dT* is the growth rate of the population at a given instant, *N* is the population size, *T* is time and *r* is the per capita rate of increase – that is, how quickly the population grows per individual already in the population. If we assume no movement of individuals into or out of the population, r is just a function of births and death rates.

There are two different growth rates which we will discuss, **exponential** and **logistic** growth.

Exponential growth is when *r* (per capita rate of increase) never changes.
Logistic growth is when *r* increases until the population reaches a maximum limit.

Exponential growth: If we were to take 1000 bacteria and let them grow in a flask, after an hour we will have 2000 bacteria. Every bacterium produced one bacterium. After 2 hours, we would have 4000 bacteria. After 3 hours, we would have 8000. The number of individuals added in each generation increases as the population increases. If you were to plot the population growth it would be a **J-shaped curve**:

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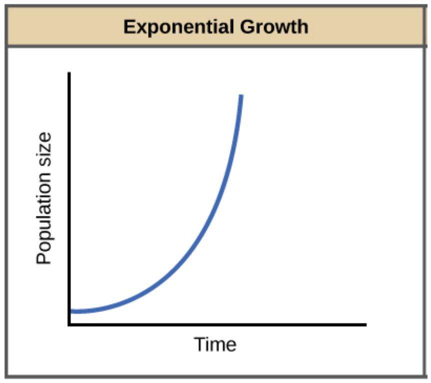
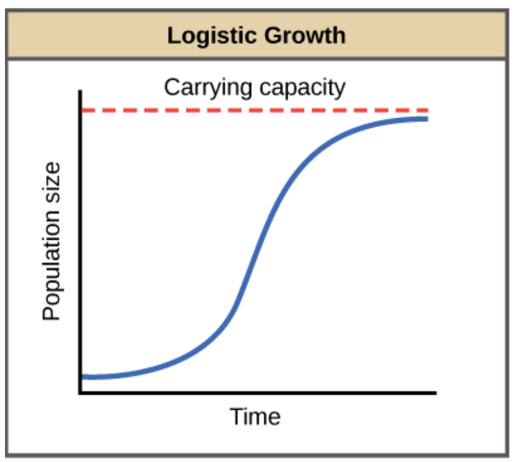


Logistic growth: Exponential growth only happens when the population is in an ideal world i.e. unlimited resources, no predators. When there are a lot of individuals in a population the number of resources decreases and this slows down the growth rate, the per capita rate of increase, *r*. Eventually, the growth rate will plateau, or level off, making an **S-shaped curve**. The population size at which it levels off, which represents the maximum population size a particular environment can support, is called the **carrying capacity**, or **K**.



We can mathematically model logistic growth by modifying our equation for exponential growth rate:

$$\frac{dN}{dT} = r_{max}\frac{(K-N)}{K}N$$

At any point in time during a population's growth, the expression *K – N* tells us how many more individuals can be added to the population before it hits carrying capacity. *(K -N)/K* is the fraction of the carrying capacity that has not yet been "used up". The more carrying capacity that has been used up, the more the *(K-N)/K* term will reduce the growth rate.

The carrying capacity of populations are determined based on food, habitat, water, and other abiotic factors. For plants, the water, sunlight, nutrients, and the space to grow are some key resources. Limited quantities of these resources result in competition between members of the same population, or **intraspecific competition** (intra - = within; -specific = species). Intraspecific competition may not affect populations that are well below their carrying capacity. However, as a

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population increases, the competition intensifies.

Materials

- Grass field or at least a 30-m field
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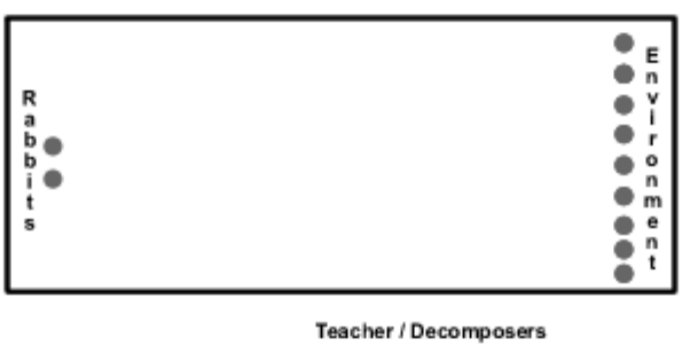
Safety

Make sure the field does not have any dangerous objects which could hurt the students when running around.

Protocol – outside activity

1. The class is going to mimic how a population of rabbits grows based upon the resources in the environment and predators. On a grass field, 2 students will stand on one side and face students 30 meters away. The side with 2 students will represent rabbits and the other side will represent resources in the environment. The teacher will stand on the side and will be the decomposing area.



2. The teacher will then tell the environment group to choose the resource they want to be and the rabbit group which resource they are searching for. Students choose their resource randomly:
    a. **Shelter = triangle over their head**

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   b. **Water = hand over their mouth**
   c. **Food = hand over their stomach**
3. Once the students have chosen their resource they cannot change it!
4. Then the environment group turns to face the rabbits (make sure to tell the students to always show their resource).
5. Each round:
   a. Rabbits run straight and once they reach the environment, they tag the resource they chose and stop. Rabbits cannot run around in the environment area searching for resources.
   b. If a rabbit tags a resource, the rabbit survives and reproduces one offspring by turning the tagged resource into a rabbit.
   c. If a rabbit does not tag the resource they were searching for, they die and go to the decomposer section.
   d. Decomposers can go to the environment after one generation. If a resource is not tagged, they stay where they are at the next generation.
6. Do this for 10 rounds and always count the number of rabbits and resources before you move on to the next round. Record the numbers in the data table.
7. On the 10th round introduce a fox. Do so by having one of the students in the decomposing section become a fox. The fox tries to tag as many rabbits as possible before the rabbits reach the environment. If the fox tags one rabbit, the fox lives. Each additional rabbit becomes a fox in the next generation. Record the number of foxes in the data per generation.

Data and Analysis

Generation	Rabbit Population	Environment Amount	Fox Population
1	2		0
2			0
3			0
4			0
5			0
6			0
7			0
8			0
9			0
10			1
11			
12			
13			

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14			
15			
16			

Graphing:

Create a line graph with population size on the y-axis against number of generations on the x-axis. Use a legend and colored pencils to graph rabbit, environment and fox populations. Mark and label exponential growth and carrying capacity on your graph.

Discussion Questions

1. What is the independent variable? What is the dependent variable? What are the constants?
2. What is the largest number of rabbits able to survive in the provided environment called?
3. Explain how the fox affected the carrying capacity of the rabbits once it was introduced.
4. Why did the dead rabbits not become an environmental resource in the next generation once the fox was introduced in the game?
5. What was the rabbit population growth rate from generation 1 to generation 5?
6. What was the rabbit population growth rate from generation 6 to generation 8?
7. What was the rabbit population growth rate from generation 9 to the last generation?

Discussion Questions—ANSWER KEY

1. What is the independent variable? What is the dependent variable? What are the constants?

The independent variable is time or generation. The dependent variable is population size. The constant is the growth rate (r).

2. What is the largest number of rabbits able to survive in the provided environment called?

Carrying capacity

3. Explain how the fox affected the carrying capacity of the rabbits once it was introduced.

The fox decreased the carrying capacity of the rabbits.

4. Why did the dead rabbits not become an environmental resource in the next generation once the fox was introduced in the game?

Because the dead rabbit was consumed by the fox and was not left in the environment to decompose.

These answers will vary since it is dependent on the actual numbers collected.

5. What was the rabbit population growth rate from generation 1 to generation 5?
6. What was the rabbit population growth rate from generation 6 to generation 8?
7. What was the rabbit population growth rate from generation 9 to the last generation?

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Protocol – inside activity

1. Prepare 5 pots by labeling each pot with 1 – 5 using tape and permanent marker.
2. Fill the pots with slightly moistened soil. DO NOT push down or pack soil.
3. Plant 2 seeds in pot 1, 4 in pot 2, 8 in pot 3, 12 in pot 4 and 24 in pot 5.
4. Cover the seeds 2 with a thin layer of soil.
5. Water plants gently from above.
6. Once you see some plants germinating, thin plants 1, 2, 4, 8, and 16 respectively.
7. Add fertilizer to the pots on days 3, 7 and 14.
8. Take measurements every day for days 3 – 18. Write down observations and measurements.
9. Harvest on day 18. Take pictures from the same distance and angle. Record information along with pot density for information for each group of plants.