

Effect of Density on Populations

Learning objective 8.4.A Explain how the density of a population affects and is determined by resource availability in the environment.

Name:

Date:

Period:

Use the tool **Something Stopping It**. Parts 1 to 3 use **One term, two curves**, Parts 4 and 5 use **What does the limiting**, and Part 6 uses **Whose property is K**. This topic is the last one plus a single factor: logistic growth is exponential growth multiplied by $(K - N)/K$. Everything separating a curve that runs away forever from one that levels off is that one multiplication, and Part 1 lets you switch it on and off with everything else held identical.

Part 1 · The same population, run twice

Identical $r(\max)$ of **0.25**, identical starting size of **10**, identical **80** steps. The only difference is whether the density term is switched on. Fill in both columns and pay attention to the top of the table as well as the bottom.

Step	Exponential (term off)	Logistic (term on)	Are they close?
0			
10			
20			
40			
80			

1. Define carrying capacity.

2. Write the logistic growth equation and identify the one factor that distinguishes it from exponential growth.

3. Explain why the two models give almost the same answer while the population is small.

Part 2 · What the term is doing

The factor $(K - N)/K$ is nothing more than **the fraction of the environment still unused**. Work it out for each population size, then multiply to get the growth rate. K is **1,000** and $r(\text{max})$ is **0.25**.

Population, N	As a share of K	$(K - N)/K$	Growth rate = $r(\text{max}) \times N \times (K - N)/K$
10			
100			
250			
500			
750			
900			
990			
1,000			

4. Explain why a logistic curve levels off.

5. Look at your last column. Explain why population growth is fastest at about half the carrying capacity, rather than when the population is largest.

6. A conservation manager wants to harvest a population sustainably, taking the largest catch the population can replace each year. Using your table, explain what population size they should aim to keep it at.

Part 3 • Two kinds of limit

A factor is density-**dependent** if its effect gets stronger as the population gets denser, and density-**independent** if it does not. Fill in both effect columns first and let them decide the type — do not sort by whether the factor sounds biological.

Factor	Effect at low density	Effect at high density	Dependent or independent?
Competition for food			
Disease transmission			
Predation			
Accumulation of waste			
Competition for nesting sites			
A hard freeze			
Drought			
A volcanic eruption			
A hurricane			

7. Distinguish between density-dependent and density-independent factors, and give three examples of each.

8. A student says predation is density-dependent because it is biological, and drought is density-independent because it is physical. Explain what is wrong with that reasoning, and state the correct test.

Part 4 • Which one can produce a carrying capacity

Two populations over **120** steps, each regulated by one kind of factor. The density-independent population is given **severe and repeated** losses — this is not a case of one factor being gentler than the other. Record what each one does.

	Density-dependent	Density-independent
Where it ends up		
How much it varies over the last 30 steps		
Does it have a carrying capacity?		
Why, or why not?		

9. Explain why only density-dependent factors can produce a carrying capacity.

10. A hurricane can kill 90% of a population. Explain why it still cannot set that population's carrying capacity.

Part 5 · Same species, four environments

Nothing about the organism changes across these four runs — same $r(\max)$, same starting population. **Only the environment changes.** Record where each settles and how long it takes, then compare the two columns against each other.

Carrying capacity, K	Population at the end	As a share of K	Steps to reach 90% of K
200			
500			
1,000			
2,000			

11. Explain why carrying capacity is a property of the environment while $r(\max)$ is a property of the species.

12. Two populations of the same species live in habitats with very different carrying capacities. Explain why they nevertheless take a similar time to fill their habitats.

13. Explain how population density both affects and is determined by resource availability.

What the model simplifies

The logistic equation is run in discrete steps rather than as a differential equation. With a large enough $r(\max)$ a discrete logistic model can overshoot its carrying capacity and even oscillate chaotically, which the continuous version never does; the $r(\max)$ used here is small enough that it approaches K smoothly.

Real populations frequently do overshoot, because organisms respond to the resources available when they were born rather than the resources available now. That time lag is left out here, and it is the main reason real populations oscillate around a carrying capacity instead of settling on it.

Carrying capacity is treated as a fixed number. In reality it moves — with the seasons, with rainfall, with what else is living there — so a population is usually tracking a moving target rather than approaching a fixed one.

The strength figures for each limiting factor are illustrative, not measurements. What is asserted about them is the structural claim: every factor labeled density-independent has an identical figure at both densities, so the labels follow the numbers rather than being applied by hand.

The regulation comparison gives the density-independent population occasional catastrophes on top of a constant death rate. That is a deliberately generous version of density independence: even with severe repeated mortality it produces no carrying capacity, which is the point.

Splitting factors cleanly into two kinds is itself a simplification. Predation is density-dependent up to a point and then saturates, because a predator can only eat so much; disease can become less effective at very high densities if survivors are immune. The categories are useful and they are not absolute.