Population Regulation in the Serengeti

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Activity
Educator Materials

OVERVIEW

In this activity, students make predictions and learn about the factors that regulate the population sizes of wildebeest and buffalo in Serengeti National Park. Students watch clips from the short film *Serengeti: Nature's Living Laboratory* featuring scientists involved in this research. They also examine and analyze authentic scientific data for these populations. At the end, students apply what they learned to other populations of their choosing.

This activity can be conducted in large classes as an interrupted case study by using the accompanying "Slide Deck," which contains links to the film clips and clicker questions to assess and develop students' understanding. Alternatively, students can complete the accompanying "Student Handout" on their own or in small groups. The handout has the same links and questions as in the slides.

Additional information related to pedagogy and implementation can be found on this resource's webpage, including suggested audience, estimated time, and curriculum connections.

KEY CONCEPTS

- Factors that affect the size of a population can be classified as bottom-up or top-down, as well as density-dependent or density-independent.
- A population can grow exponentially when it is small and has many resources. But most populations are eventually limited by density-dependent factors, which results in logistic growth.
- Migration can affect which factors limit a population's growth, as well as the ultimate size of the population.

STUDENT LEARNING TARGETS

- Explain how different factors (top-down/bottom-up, density-independent/density-dependent) regulate population sizes and apply an understanding of these terms to real populations.
- Compare and contrast exponential and logistic population growth, recognizing the carrying capacity associated with the latter.
- Make predictions and use scientific evidence to identify factors that affect the growth of actual populations.
- Use evidence to infer how migration changes the impact of density-dependent factors on population growth.
- Interpret graphs to make claims based on evidence.

PRIOR KNOWLEDGE

It is helpful for students to be familiar with:

- top-down and bottom-up population regulation factors
- density-independent and density-dependent population regulation factors
- exponential and logistic population growth, including carrying capacity

Some of these terms are briefly explained in the handout and slides, but you may need to provide additional explanations and support if students are unfamiliar with these concepts.

MATERIALS

- access to the film clips
- slides from the "Slide Deck" and/or copies of the "Student Handout"

BACKGROUND

The short film *Serengeti: Nature's Living Laboratory* explores the foundational research in Serengeti National Park, Tanzania, that uncovered many of the ecological principles that govern how animal populations and communities are regulated. The full film tells the story of how ecologists Tony Sinclair, Simon Mduma, and Grant Hopcraft spent five decades piecing together the mystery of what makes the Serengeti the way it is and the central role wildebeest play.

As discussed in the film, there are two different types of wildebeest populations in the Serengeti: migratory and nonmigratory. The migratory population consists of over a million individuals that migrate seasonally. The nonmigratory population consists of a few thousand individuals that do not migrate and instead stay in particular parts of the park.

The film is divided into three main chapters. Chapter 1 explores the phenomenon of the sudden increase in wildebeest and buffalo populations and connects to the concepts of top-down and bottom-up regulation and carrying capacity. Chapter 2 explores how migration allows wildebeest to reach enormous numbers. Chapter 3 explores how wildebeest indirectly affect many other components of the ecosystem, making them a keystone species.

This activity focuses on parts of the film related to population regulation and explores content from Chapters 1 and 2 only. It uses five short clips from the film, as well as one optional clip:

- Video clip 1 (0:11–2:22) introduces the Serengeti and its animals.
- Video clip 2 (3:39–5:49) describes the exponential growth of buffalo and wildebeest populations starting in the early 1960s, after the elimination of a virus called rinderpest.
- Video clip 3 (5:50–7:03) shows how, over time, the wildebeest population eventually reached a carrying capacity.
- Video clip 4 (11:44–14:18) describes research that determined migratory wildebeest were limited by food availability.
- Video clip 5 (21:38–27:37) discusses the Serengeti wildebeest migration. It also explores the role of predation in regulating migratory versus nonmigratory wildebeest populations.
- The optional clip (8:23–9:27) explains the difference between bottom-up and top-down population regulation.

TEACHING TIPS

- This activity can be completed in two 50-minute class periods. If there are fewer discussions with classmates, or if background information was covered in previous classes, the activity could be completed in one 50-minute class period, especially if the last parts are assigned as homework.
- You can do this activity using the accompanying "Slide Deck," "Student Handout," or both depending on what works best for your class.
    - The slides and handout are alternative ways of presenting the same content: they both contain the same information, video clips, questions, etc. (Due to space constraints, the wording of some questions on the slides may differ slightly from those on the handout.)
    - The **"Student Handout"** can be completed by students on their own or in small groups, either in class or as homework.
        - Consider distributing Parts 1–4 separately, as later parts may answer some of the questions in the earlier parts.
    - The **"Slide Deck"** is designed for large classes that use clicker questions. Project the slides to students and use a think-pair-share strategy for each of the questions.

    - Consider describing to the class how you would like them to interact with clicker questions in general and any class norms you have for the process.
    - It is recommended to review each question, including each distractor, as a class after students have discussed their ideas with a partner.
    - While the slides can stand alone as an in-class activity, it may be helpful for students to also have the "Student Handout" as they view the slides. This can encourage them to take notes during the activity and provides a space for them to record and review their answers.
- Before doing the activity, decide how much background information your students will need to understand bottom-up/top-down and density-dependent/density-independent population regulation factors, as well as exponential and logistic population growth.
  - The optional clip from the film can be used to introduce bottom-up/top-down regulation.
  - The *Population Dynamics* Click & Learn provides more information on exponential and logistic growth models.
- The activity contains an optional question (after Question 13 in the "Student Handout" and on Slide 16 of the "Slide Deck"). Decide if you want students to complete that question and edit the documents accordingly.
- At multiple points in the activity, students will be asked to first answer a question or make a prediction on their own, sometimes before they have learned everything they need to know.
  - Tell students that this strategy allows them to reflect on their current understanding, which may get modified in a discussion with a classmate or instructor, and that they will have an opportunity to revise their answers.
  - To encourage students to meaningfully participate, remind them that they will *not* be penalized for a wrong initial answer.
- Video clips are embedded in the "Slide Deck" and will play after clicking on the slide.
  - To provide better accessibility for students, turn on closed captioning while playing the clips.
  - PowerPoint may block playback for video clips. You may need to select an "Enable Content" option to allow them.

PROCEDURE (FOR THE "SLIDE DECK")

Use the following steps to present the "Slide Deck" in class. The corresponding steps in the "Student Handout," which students can complete in class or on their own, are also shown.

PART 1: Populations in Serengeti National Park

Slide 2 (Step 1 in the "Student Handout")

Introduce Serengeti National Park and show students where it is located (Tanzania in central Africa, covers 14,750 km^2). Have students predict what animals they would expect to find in the park and generate a class list that is projected to students.

Play video clip 1, which shows beautiful imagery of the Serengeti and the animals living there. (This and all the other video clips are embedded in the slides and linked in the "Student Handout.") The clip is narrated by Tony Sinclair, a Serengeti ecologist and professor emeritus at the University of British Columbia.

Slide 3 (Step 2 in the "Student Handout")

Present the idea that populations have the capacity to grow exponentially, but they usually can't sustain exponential growth for long periods of time. The reason is that many things limit a population's growth and size. Prompt students to list factors that could limit a population's growth and size by asking them to think about the animals they saw in the previous video clip. Factors could include predation, parasitism, food, habitat, water, nutrients, natural disasters, etc.

As students describe various factors, discuss whether each factor is top-down/bottom-up and density-independent/density-dependent; these terms are briefly defined in the "Student Handout." (You will likely need to prompt students for examples of top-down and density-independent factors, as these are not frequently mentioned by students.) Note that not all factors will fit cleanly into one category or the other.

If students are unfamiliar with bottom-up/top-down and density-independent/density-dependent factors, first identify a specific factor and explain what these terms mean in the context of that factor. The images on the slide can help support this discussion. (You may also want to use this optional video clip to introduce top-down/bottom-up factors. This clip includes Simon Mduma from the Tanzania Wildlife Research Institute.) Afterward, prompt students to classify the remaining factors.

Slide 4 (Step 3 in the "Student Handout")

Explain that this case study will focus on two important herbivores in the Serengeti, buffalo and wildebeest, with a stronger emphasis on wildebeest. There are two different types of wildebeest populations in the Serengeti: migratory (those that move seasonally through the Serengeti) and nonmigratory (those that stay in particular parts of the park).

Have students answer the corresponding clicker question. They should answer it first on their own, then discuss with a classmate. Afterward, discuss the question with the whole class. (Consider describing to the class how you would like them to interact with clicker questions in general and any class norms you have for the process.)

The answer is **C) rainfall**. Rainfall impacts plants, which these animals depend on for food, and is thus a bottom-up factor. The number of lions or parasites may also affect a population's size, but they are top-down factors instead. Earthquakes are density-independent and are neither top-down nor bottom-up.

PART 2: What Happened to Migratory Wildebeest? (1958–1978)

Slide 5 (Part 2 introduction in the "Student Handout")

Play video clip 2, which describes what happened to the buffalo and wildebeest populations starting in the early 1960s, after the elimination of a virus called rinderpest. The clip also briefly describes population surveys.

Before going to the next slide, you may want to discuss why it was interesting to Sinclair that the populations of wildebeest and buffalo were increasing. The answer is that populations are usually somewhat stable, especially populations of large, slowly reproducing animals like these.

Slide 6 (Step 4 in the "Student Handout")

Have students identify which symbols on the figure (unshaded squares or shaded circles) represent the number of wildebeest, and which represent the percentage ("prevalence") of wildebeest with rinderpest. Discuss how they know.

Once students identify that the shaded circles represent the wildebeest population size and the unshaded squares represent the prevalence of rinderpest, proceed to the next slide. Later in the activity, students will see a figure that extends this data to 2003.

Slide 7 (Step 5 in the "Student Handout")

Ask students to brainstorm the clicker question individually or in groups. The answer is **C) density-dependent, top-down**. Classifying the virus as a top-down factor is challenging, as it is not as clear as classifying a predator as top-down.

Slide 8 (Steps 6 and 7 in the "Student Handout")

Ask students to consider the clicker question individually, then discuss it in pairs. The answer is **A) exponential**. This question is a probe to help you recognize the extent to which your students understand the terms "exponential" and "logistic." Some may have learned about them in math class but have not yet applied them to biology. If many of your students struggle with these terms, you will want to provide additional explanations and support.

Next, have students brainstorm what may happen to a population if it continues growing exponentially. You may want to provide specific predictions for what will happen, such as the population leveling off, crashing, or declining.

PART 3: What Happened to Migratory Wildebeest? (1958–2003)

Slide 9 (Part 3 introduction in the "Student Handout")

Watch video clip 3, which explains what happened to the wildebeest population over time: the population kept growing for a while but eventually peaked. Tie this back to the discussion from the previous slide, in which students likely suggested that the population wouldn't be able to grow forever. The clip ends with the question "Why did the wildebeest population stop growing?"

Slide 10 (Step 8 in the "Student Handout")

The figure on this slide is the full version of the figure on the previous slides, and it shows the growth of the wildebeest population over a longer time period. Have students think about the full shape of the population's growth curve to answer the clicker question. The answer is **c) logistic**.

Note that logistic growth, unlike the other options, is characterized by a limit to growth. Explain that this limit is called the carrying capacity, and that it is the largest population size that the environment can support in the long run.

Slides 11 and 12 (Steps 9 and 10 in the "Student Handout")

The answer is **C) 1,300,000**. Note that the population fluctuates around this value due to natural variations in population size and other biotic and abiotic factors.

Have students briefly discuss what factors could be affecting the size of the wildebeest population from around 1980 to 2000, and whether these factors were likely to be density-dependent or density-independent.

PART 4: Nonmigratory versus Migratory Wildebeest

Slides 13 and 14 (Steps 11 and 12 in the "Student Handout")

This section switches the focus from the migratory wildebeest discussed in the previous examples to wildebeest that do not migrate. Tell students they will now start thinking about what limits the growth of the nonmigratory wildebeest population.

First, they will examine a figure that shows data on *nonmigratory* Serengeti herbivores. It compares the log of herbivore weight (you may need to explain log scale to students) and the percentage of deaths in the population due to predation. In the figure shown in the slides, the wildebeest data point has been removed.

Give students time to discuss the questions on these slides in pairs or small groups before sharing as a class. For the question on Slide 13 (Step 11 in the handout), students may recognize that as the herbivores get larger, they may be more difficult for predators to kill. For the question on Slide 14 (Step 12 in the handout), students will likely suggest other density-dependent factors, such as lack of food, water, or habitat.

Slide 15 (Step 13 in the "Student Handout")

This slide reveals the wildebeest data point (W) on the figure; note that it appears as an animation after clicking. The answer to the clicker question is **B) 85%**.

Reiterate that these data are for nonmigratory wildebeest, which have a population size in the few thousands. Highlight that the factors affecting the migratory wildebeest are different.

Slide 16 (Optional Question in the "Student Handout")

Show video clip 4, which features Simon Mduma from the Tanzania Wildlife Research Institute. You may wish to have students answer the optional question below, which does not appear on the slides.

Optional Question: Which of the following data best supports the idea that migratory wildebeest are limited by *bottom-up* factors?

a. The population increases during the dry season.
b. The bone marrow of dead wildebeests was translucent and gelatinous in the dry season.
c. There were many animal markings on the bones.

The answer is **B**, which indicates that the wildebeest were starving and limited by food.

Slide 17 (Introduction to Step 14 in the "Student Handout")

Summarize what students have learned so far about the factors that limit migratory and nonmigratory wildebeest. Prompt students for ideas for why nonmigratory wildebeests are limited by predation, but migratory wildebeest are limited by food instead. Then, show video clip 5, which features Grant Hopcraft from the University of Glasgow.

Slide 18 (Step 14 in the "Student Handout")

Have students reflect on what limits the migratory population by answering the clicker question. The answer is **D) density-dependent, bottom-up**.

Slide 19 (Steps 15 and 16 in the "Student Handout")

Have students reflect on what limits the nonmigratory population by answering the clicker question. The answer is **C) density-dependent, top-down**.

Ask students to discuss and summarize why the limiting factors are different between the two groups of wildebeest.

Slide 20 (Steps 17 and 18 in the "Student Handout")

Describe how wildebeest aren't the only animals that migrate in the Serengeti. Ask students to discuss the following question: "What factors might limit migratory versus nonmigratory populations of other animals, such as zebras and gazelles?" It may be helpful for students to see the figure on Slide 15 again, in order to compare these animals to wildebeest.

Finally, see if students can apply what they learned by answering the following question: "Think of a population outside the Serengeti that you are familiar with, maybe one that lives near you. What factors do you think limit the size and growth of the population you chose? Why?"

ANSWER KEY (FOR THE "STUDENT HANDOUT")

For all the multiple-choice questions (Questions 3, 5, 6, etc.), encourage students to predict answers on their own, but don't penalize them for wrong initial answers. This practice encourages students to reflect on their prior ideas and check their understanding, a useful metacognitive habit.

PART 1: Populations in Serengeti National Park

1. Serengeti National Park covers a large region (14,570 km^2) in central Africa and is home to many species of animals. List some of the animals you would expect to find in the park.
   Student answers will vary.

2. Think about the animals you saw in the video clip and the factors that could limit the size and growth of their populations. Fill out Table 1 with your predictions.
   Sample answers are provided in Table 1 below.

Table 1. Factors that could limit the size and growth of populations.

Factor	Bottom-up or top-down?	Density-dependent or density-independent?
Predation	***Top-down***	***Density-dependent***
Parasitism	***Many would classify this as top-down, but its classification is a gray area.***	***Density-dependent***
Food	***Bottom-up***	***Density-dependent***
Habitat	***Bottom-up***	***Density-dependent***
Weather	***Neither***	***Density-independent***
Water	***Bottom-up***	***Density-dependent***
Fire	***Neither***	***Density-independent***

3. This case study focuses on two important herbivores in the Serengeti: buffalo and wildebeest. Their populations are strongly affected by certain bottom-up factors. Which of the following is a **bottom-up** factor that could impact the population sizes of these herbivores?
   a. predators, such as lions
   b. parasites
   c. rainfall
   d. earthquakes

PART 2: What Happened to Wildebeest? (1958–1978)

4. In Figure 1, which symbol (unshaded square or shaded circle) represents the number of wildebeest, and which represents the percentage (“prevalence”) of wildebeest with rinderpest? How do you know?
   Video clip 2 describes how wildebeest populations were “skyrocketing” in the 1960s. This suggests that the shaded circles, which are increasing in Figure 1, represent the wildebeest population. The clip also describes how rinderpest was eliminated through a vaccination program around the same time. This suggests that the unshaded squares, which are decreasing in Figure 1, represent the percentage of wildebeest with rinderpest.

5. The elimination of rinderpest impacted the wildebeest population. What type of factor is rinderpest?
   a. density-independent, top-down
   b. density-independent, bottom-up
   c. density-dependent, top-down
   d. density-dependent, bottom-up

6. Consider the growth curve of the wildebeest population shown in Figure 1. Which of the following best describes this type of growth?
   a. exponential
   b. linear
   c. logistic
   d. geometric

7. Predict what would happen to the wildebeest population in the long term given this type of growth.
   If the population continued to grow exponentially, it would eventually run out of space or food, or be affected by some other density-dependent factor, which would limit the size of the population.

PART 3: What Happened to Wildebeest? (1958–2003)

8. Consider the entire growth curve for the wildebeest population shown in Figure 2. Which of the following best describes this type of growth?
   a. exponential
   b. linear
   c. logistic
   d. geometric

9. Based on Figure 2, what is the wildebeest population's approximate carrying capacity (the largest size of a population that the environment can support in the long run)?
   a. 800,000
   b. 900,000
   c. 1,300,000
   d. 1,500,000

10. In 1958, the wildebeest population was relatively small due to rinderpest. What factors may have affected the size of the wildebeest population from around 1980 to 2000? Were these factors likely to be density-dependent or density-independent? Why?
    The wildebeest population leveled off at around 1.3 million from 1980 to 2000. Students may suggest a variety of factors that could have limited the population, such as food, water, habitat, or predation. Because these factors limited the population size only when the population was large, they would be considered density-dependent factors.

PART 4: Nonmigratory versus Migratory Wildebeest

11. What might explain the relationship between predation and herbivore weight shown in Figure 3?
    Be open to a range of logical student ideas. Students may recognize that as the herbivores get larger, they may be more difficult for predators to kill.

12. Some of the herbivore populations in Figure 3 have very few deaths, if any, due to predation. What factors are likely to limit the sizes of these populations?
    These populations may have been limited by other density-dependent factors. These could be bottom-up factors such as food, water, or habitat, or top-down factors not including predation.

13. Approximately what percentage of nonmigratory wildebeest deaths are caused by predation?
    a. 100%
    b. 85%
    c. 45%
    d. 25%

Optional Question: Which of the following data best supports the idea that migratory wildebeest are limited by *bottom-up* factors?
   a. The population increased during the dry season.
   b. The bone marrow of dead wildebeests was translucent and gelatinous in the dry season.
   c. There were many animal markings on the bones.

14. Migratory wildebeest populations are limited mainly by factors that are:
    a. density-independent, top-down

- b. density-independent, bottom-up
- c. density-dependent, top-down
- ***d. density-dependent, bottom-up***

15. Nonmigratory wildebeest populations are limited mainly by factors that are:
    - a. density-independent, top-down
    - b. density-independent, bottom-up
    - c. ***density-dependent, top-down***
    - d. density-dependent, bottom-up
16. Explain why nonmigratory and migratory wildebeest populations are limited by different types of factors.
    As shown in Figure 3 and explained in video clip 5, most nonmigratory wildebeest die due to predation, so they are limited by predators. Migratory wildebeest, on the other hand, are able to avoid high rates of predation because their predators do not migrate. As a result, migratory wildebeest are limited by their food supply rather than by predators.
17. Wildebeest aren't the only animals that migrate in the Serengeti. What factors might limit migratory versus nonmigratory populations of other animals, such as zebras? (*Hint:* You may want to look at Figure 3 again.)
    Figure 3 shows that nonmigratory zebras are similar to nonmigratory wildebeest in terms of both body weight and percentage of deaths due to predation. As a result, nonmigratory populations of zebras may be limited by predation and the migratory populations limited by food, similar to wildebeest.
18. Think of a population outside the Serengeti that you are familiar with, maybe one that lives near you. What factors do you think limit the size and growth of the population you chose? Why?
    Be open to a range of logical student ideas.

REFERENCES

The first graph is from the Data Point "Serengeti Wildebeest Population Regulation," which is based on:
Holdo R. M. (2009). "A disease-mediated trophic cascade in the Serengeti and its implications for ecosystem C." *PLoS Biology*. https://doi.org/10.1371/journal.pbio.1000210.

The second graph is from the Data Point "Patterns of Predation," which is based on:
Sinclair, A. R. E., Simon Mduma, and Justin S. Brashares. "Patterns of predation in a diverse predator–prey system." *Nature* 425, 6955 (2003): 288–290. https://doi.org/10.1038/nature01934.

CREDITS

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