Niche Partitioning Activity

OVERVIEW

In this activity, students make claims about different niche partitioning mechanisms based on scientific data. The activity begins with students interpreting a graph about dietary niche partitioning by grazers on the African savanna. Students then watch two short videos, one on niche partitioning and the other on DNA metabarcoding, and answer questions to apply what they have learned.

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

- Ecological communities are structured, in part, by interactions between different species.
- Niche partitioning is an example of cooperative behavior between populations that contributes to their survival.

STUDENT LEARNING TARGETS

- Analyze graphs and explain trends in the data.
- Explain how behavior that benefits populations involves timing and coordination of activity.
- Describe different mechanisms of niche partitioning.
- Evaluate a classical understanding of niche partitioning in light of new data.

PRIOR KNOWLEDGE

It is helpful for students to have some familiarity with:

- the ecological concept of a niche
- species interactions, such as competition and facilitation
- different types of herbivores, such as grazers and browsers
- the African savanna ecosystem
- interpreting line graphs and scatterplots

MATERIALS

- copies of the "Student Handout"
- access to the "Niche Partitioning" and "Metabarcoding" video clips, which can also be downloaded from this activity's webpage

TEACHING TIPS & SEQUENCE

- The "Student Handout" is designed to guide students through the activity at their own pace. However, you might choose to begin with a discussion or to have all students work on the same section at the same time.
- In Part 1 of the activity, students interpret a line graph showing dietary niche partitioning by grazers on the African savanna by time and grass height.

- This graph is based on Figure 2 from du Toit and Olff (2014). The same graph is also discussed at the end of the "Niche Partitioning" video clip, which students will watch in Part 2 of this activity.
- You may choose to quickly introduce the three grazers shown in Part 1: zebra, wildebeest, and Thomson's gazelle. For photographs of the animals, you could visit the African Wildlife Foundation's Wildlife Gallery, as well as WildCam Gorongosa's Field Guide (on the Classify page) and Collections.
- You might choose to discuss the concept of a fundamental versus a realized niche, especially for zebra, with the class. Ask students to brainstorm ways to test their ideas about zebras' fundamental versus realized niches. What other data would they need, and how could they collect it?

- In Parts 2 and 3 of the activity, students watch two video clips from the 2015 Holiday Lecture "How Species Coexist" to learn more about niche partitioning and how it is studied.
  - Both video clips can be accessed via the links below or downloaded from this activity's webpage. The "Student Handout" also contains the links provided below.
  - The first video clip, "Niche Partitioning," describes several classical niche partitioning mechanisms. It provides examples of herbivores in the African savanna partitioning their habitat by space (spatial niche partitioning) and diet (dietary niche partitioning), the latter of which may involve dividing food resources based on time or height (as shown in Part 1 of this activity).
  - The second video clip, "Metabarcoding," describes a technology that allows scientists to determine herbivore diets based on the sequences of plant DNA extracted from animal dung.
  - After watching the second clip, students are asked to interpret a graph of herbivore dietary differences.
    - This graph is based on Figure 4a from Kartzinel et al. (2015) and uses data from DNA metabarcoding. It also appears in the "How Species Coexist" Holiday Lecture starting around 16:33.
    - This graph was generated using nonmetric multidimensional scaling. NMDS is briefly described in the "Student Handout" but may be unfamiliar to students. If students are struggling with this graph, consider discussing it as a class and/or providing additional support.
- Part 4, the last part of the activity, has students apply niche partitioning concepts. You can have students do the Part 4 questions individually, or you can pose them as small-group or large-group discussion questions.
- This activity can be supplemented with related resources, such as the following:
  - Multiple BioInteractive resources allow students to apply concepts from this activity to other examples. For instance, the short film *The Origin of Species: Lizards in an Evolutionary Tree* and the *Lizard Evolution Virtual Lab* explore niche partitioning in anole lizards.
  - Other resources, such as the article "Humanity's Grassroots: How Grazing Animals Shaped Evolution" and the corresponding *PNAS* paper (Uno et al. 2011), could be used to explore the history and importance of grazers in the African savanna.

ANSWER KEY

PART 1: Niche Partitioning by Time and Grass Height

1. Describe how the relative zebra density changes over time. What characteristics of zebras could explain why zebra densities are greatest when the *P. maximum* grass is tallest and most abundant?
   Right after the peak rain, zebras have the highest relative density of all three grazers. The zebra relative density reaches its maximum one month after the rain, decreases to nearly zero three months after the rain (when the wildebeest density is highest), and then increases to about 0.3 six months after the rain.

   The reason that zebra densities are greatest when the grass is tallest and most abundant is because, out of these three grazers, zebras get the most out of eating tall grass. Zebras' teeth allow them to eat taller

grasses with many stems. Zebras can also digest grass faster. Although their digestion is less efficient than that of the ruminant grazers, and the tall grass is less nutritious because it has many stems, zebras can just eat a lot of the grass and digest it quickly to get the nutrition they need.

2. Describe how the relative wildebeest density changes over time.
The relative density of the wildebeest population is nearly zero for two months after the peak rain, increases to its maximum three months after the rain, then declines to nearly zero again by five months after the rain.

3. Propose a reason or reasons why the relative wildebeest density spikes when it does. Support your idea with evidence from what you know about wildebeests and *P. maximum* grass. (*Hint:* Remember that the more nutritious parts of the grass are closer to the ground. The grasses continue to grow after being grazed, and the parts that grow back are also more nutritious.)
The wildebeest density spikes about three months after the peak rain. By this point, the **P. maximum** ***grass has already been grazed by zebras, which were most common in the months prior. The zebras eat the tops of the grass, making it easier for wildebeests to access the more nutritious parts of the grass near the ground. The parts of the grass that grow back after the zebras graze are also more nutritious.***

   Since wildebeests are ruminants, they cannot digest food as quickly as zebras do, but they can get more energy and nutrients from a smaller amount of food. So, it is probably advantageous for them to eat the grass that the zebras have grazed even if it is not as tall, since it is more nutritious.

4. Describe how the relative Thomson's gazelle density changes over time, in relation to the changes in the wildebeest population density and in the grass height. Why do you think this is so?
The relative density of the gazelle population is low (around 20%–30%) until 2 months after the peak rain, at which time it begins steadily increasing to its maximum, at about 5 months after the rain. By this point, the wildebeest relative density has returned to nearly zero, and the grass height is very short.

   In general, it appears that the gazelle density increases as the grasses get shorter due to grazing by the zebras and wildebeests. This could be because, like wildebeests, gazelles are ruminants that benefit from more nutritious food even if it is less abundant. When the grasses are grazed by other animals first, the gazelles have greater access to the more nutritious parts. Because gazelles are smaller than wildebeests, they need less energy overall. So they can thrive on the shortest grass even if the other animals cannot get enough energy from it.

5. Would you describe the interactions between zebras, wildebeests, and Thomson's gazelles as competition or facilitation among species? Support your answer with data from Figure 1.
Student answers may vary but should be supported with logic and evidence from the graph above. Note that ecologists tend to view this as a positive interaction, such as facilitation, rather than a competitive one.

PART 2: Types of Niche Partitioning

6. Complete the following table based on what you learned. Include both a general description and a specific example for each row.
Student examples may vary. Sample answers are provided on the next page.

Type	Description	Example
Spatial niche partitioning	***Different species occupy different spaces in a habitat.***	***Different antelope species live in different places in the same habitat (reedbuck in the reeds, nyala in the woods, etc.).***
Dietary niche partitioning	***Different species eat different things.***	***Some herbivores, such as zebras, eat mostly grass. Others, such as dik-diks, eat mostly other plants like shrubs and trees.***
Niche partitioning by resource height	***Different species access resources at different heights.***	***Tall herbivores, such as giraffes, usually eat from the higher parts of a tree. Shorter herbivores, such as kudu or steenbok, eat from the lower parts of a tree.***
Niche partitioning by time (temporal niche partitioning)	***Different species access resources at different times.***	***As shown in Part 1, zebras, wildebeests, and Thomson's gazelles eat* P. maximum *grass at different times after the peak rain. Zebras eat the grass right after the rain, when it is tallest, and gazelles eat the grass several months after, when it is shortest. Wildebeests eat the grass in between these two periods, when it is of intermediate height.***

PART 3: Investigating Dietary Niche Partitioning with Metabarcoding

7. In general, how does the diet of the plains zebra compare to that of the Grevy's zebra? Are they eating the same species of plants?
Figure 2 shows that the data points for these species are in distinct clusters with some overlap. This suggests that the two species have distinct diets and do not eat all of the same plants. However, there are probably some types of plants they both eat because there is some overlap in their diets.

8. In general, how does the diet of the plains zebra compare to that of the impala?
Figure 2 shows that the data points for these species are in distinct clusters without any overlap. This suggests that they have very different diets.

9. How might the data in Figure 2 provide a greater understanding of the grazer-browser spectrum?
Figure 2 supports the grazer-browser spectrum by showing separation among the diets of grazers and browsers along the x-axis. However, the figure adds to our understanding of the spectrum by showing additional variation within grazers or browsers along the y-axis. For example, although zebras are all grazers, different species of zebras (plains and Grevy's) do not have the exact same diets and are probably eating some different species of plants.

10. Figure 2 includes six wild species and one domesticated species: cattle. How might these data inform wildlife management near areas with farming and/or ranching of domesticated animals?
These data could help determine whether the wild and domesticated species eat the same types of plants and would thus compete for food. This information could help farmers and ranchers decide when it would be useful, or not useful, to remove or restrict wildlife from their lands.

11. The data in Figure 2 are from a single wet (rainy) season. Why would it be important to run the experiment again during other seasons?
In other seasons, there may be less rain and thus fewer plants, so animals may have to shift their diets. If so, the patterns shown in Figure 2 could change. The species' diets might begin to overlap more, especially if there are fewer plants to choose from, or they might shift to other distinct diets.

PART 4: Applications of Niche Partitioning

12. For each of the examples in the following table, identify the mechanism by which the resources, and thus the niches, are divided. Use the niche partitioning mechanisms you described in Question 6.

Mechanism	Description and example
Niche partitioning by time	During the warm daylight hours, bees collect nectar from the flowers on a linden tree. In the evening, different types of moths are on the flowers.
Dietary niche partitioning	Two types of birds, pileated woodpeckers and yellow-bellied sapsuckers, get food from the same tree. Sapsuckers drill rows of little holes to eat the tree's sap and insects in the sap. Pileated woodpeckers dig deep holes to find insects in the tree trunk.
Spatial partitioning ***or*** ***Niche partitioning by resource height***	Prairie grasses use their roots to get water and nutrients from the soil. Smartweed roots reach nearly 100 cm underground, Indian mallow roots reach 70 cm, and bristly foxtail roots reach only about 20 cm.

13. Which of the following statements best describes niche partitioning?
    a. Varying prey species maintains biodiversity.
    b. Superior species enjoy success because of competitive exclusion.
    c. Coevolution between two species means they can always share the same niche.
    d. Similar species can coexist because of slight differences in each one's niche.

14. How can niche partitioning increase biodiversity?
    Niche partitioning can increase biodiversity by giving multiple species access to a limited resource. By dividing up the resource in such a way that the species don't have to compete with one another, a greater number of species are able to survive.

REFERENCES

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CREDITS

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