NICHE PARTITIONING: UPDATING AN OLD PARADIGM

OVERVIEW:

An organism's niche is its place and role in an ecosystem, including where it lives and how it obtains the resources it needs to survive. If competing species use the environment differently, or partition resources, they can coexist in the same area; niche partitioning facilitates coexistence of similar species in a habitat. In this activity, students use data presented in the HHMI 2015 Holiday Lecture "How Species Coexist" to explore the concept of niche partitioning, learn about mechanisms of niche partitioning, and consider the classic grazer-browser spectrum paradigm in light of new dietary data obtained from DNA metabarcoding.

KEY CONCEPTS AND LEARNING OBJECTIVES:

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

Students will be able to:

- Analyze graphs and explain trends in the data.
- Articulate how an organism's realized niche might differ from its fundamental niche.
- 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.

CURRICULUM CONNECTIONS:

Curriculum	Standards
NGSS (April 2013)	HS.LS2.A, HS.LS2.C SEP: Analyzing and Interpreting Data
AP Biology (2012-2013)	2.E.3 Science Practices: Data Analysis and Evaluation of Evidence
IB Biology (2016)	4.1, Option C.1

KEY TERMS

Niche, niche partitioning, fundamental niche and realized niche

TIME REQUIREMENTS

This lesson was designed to be completed in one or two 50-minute periods.

MATERIALS

Student worksheet

Video excerpts from the Holiday Lectures, which can be downloaded from the webpage for this activity or student access to the 2015 HHMI Holiday Lecture 3, "How Species Coexist."

SUGGESTED AUDIENCE

This lesson is appropriate for all levels of high school biology.

PRIOR KNOWLEDGE

Some knowledge of ecological concepts (niche, species interactions) and the savanna ecosystem is useful.

TEACHING TIPS & SEQUENCE

The student worksheet 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.

1. In the first part, students are asked to interpret a graph about dietary niche partitioning by grazers on the African savanna by time and grass height.
    a. It's important that students can distinguish between a zebra, wildebeest, and Thomson's gazelle; you may choose to quickly introduce those three organisms. For a quick look at the animals, visit https://www.wildcamgorongosa.org/#/field-guide and http://www.awf.org/wildlife-conservation/thomsons-gazelle.
    b. You might choose to discuss the concept of a fundamental versus a realized niche, especially for zebra. 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?
2. During the second part, students watch five minutes of the 2015 HHMI Holiday Lecture 3, "How Species Coexist" from 3:35 – 7:48 and describe each of the classical niche-partitioning mechanisms.
3. Students are then introduced to DNA metabarcoding through another lecture clip from the 2015 HHMI Holiday Lecture 3, "How Species Coexist" (10:48 – 13:47), and they interpret a plot of data about herbivore dietary differences.
4. The final section is application questions. You can have students do these individually, or you can pose them as small-group or large-group discussion questions.

ANSWER KEY

1. Describe how the density of zebras grazing on *Panicum* grasses changes over time. What characteristics of the zebra explain why zebra numbers are greatest when the grass is tallest and fullest?

    Zebras are the first to move in and eat the tall, stem-filled grass. The density of the grazing zebra population at one month after the peak rain is at its maximum, then decreases to nearly zero about three months after the rain (when the wildebeest population is highest) and then begins to increase again to about 30% at six months after the rainy season. Zebras' teeth allow them to eat taller grasses with thicker stems. Although a zebra's digestive system is less efficient than that of a ruminant, zebras are able to extract nutrients from lower quality grass. They just need to eat a lot of grass to get the nutrition they need.

2. Describe the trend in wildebeest grazing population density over time.

    The density of the wildebeest grazing population is nearly zero until two months after the rain and then increases to its maximum three months after the peak rain, then declines to nearly zero again by five months after the rain.

3. Propose a reason or reasons that the wildebeest population density spikes when it does. Support your idea with evidence from what you know about wildebeest and *Panicum*. (Hint: Grasses continue to grow after being grazed.)

    The wildebeest population grows and spikes after the **Panicum** *grass has already been grazed by zebras and therefore is shorter, allowing greater access to the more nutritious part of the grass and to the new growth. Wildebeests are ruminants and are adapted to consume smaller quantities of food than hindgut fermenters like zebras. Wildebeests prefer grass that is less tall and is slightly higher quality than that which the zebras consume.*

4. How does the gazelle population density change in relation to the changes in the wildebeest population density and the grass morphology over time? Why do you think this is so?

    The density of the gazelle grazing population is low (20%-30%) until 2 months after the peak rain, at which time it begins steadily increasing to its maximum population density, at about 5 months after the peak rain (coinciding with the wildebeest grazing population density being very low again). The gazelle population density increases as the grasses decrease in length due to grazing by the other organisms. The gazelles eat **Panicum** *grass when it is shortest, when they have access to the more nutritious lower and new growth. As ruminants, they can extract more nutrition from a smaller quantity of high-quality grass. They are also the smallest of the three and need less energy overall to support their body size.*

5. Would you describe the interactions between zebras, wildebeests, and gazelles as competition or facilitation between species? Explain with data from above.

    Facilitation. Student answers will vary, but should be supported with logic and evidence from the graph above. Note that ecologists tend to view this as a positive rather than a competitive interaction.

6. Types of Niche Partitioning:

Mechanism	Description & example
Spatial niche partitioning	*Different species occupy particular spatial niches in the habitat. Ex: different antelope species live in slightly different spots (reedbuck in the reeds and nyala in the woods or anole lizards in the tree canopy).*
Dietary niche partitioning	*Organisms separate resources by what they eat. Grazer–browser spectrum: some organisms eat only grass, others eat only trees, and others eat some of both.*
Niche partitioning by plant height	*Animals separate out by height. Tall browsers (giraffes) eat from the tall part of the tree most of the time, while the short dik-dik eats the low parts of the tree.*
Niche partitioning by time and grass height	*Grazers eat at different times. Grazing succession & facilitation.*

7. How does the diet of the plains zebra compare to that of the Grevy's zebra? Are they eating the same species of grass?

    The diet of the Grevy's zebra is different from that of the plains zebra, and they do not eat all of the same grasses. However, their diets are fairly similar and there are some species of grass that they both eat.

8. How does the diet of the plains zebra compare to that of the impala?

    The plains zebra appears to have a very different diet than that of the impala; their data points do not overlap.

9. What does this new data contribute to our understanding of the grazer-browser spectrum and dietary niche partitioning?

    These new data provide a greater understanding of niche partitioning. The grazer-browser spectrum provides a simple explanation of dietary niche partitioning: some organisms only graze (eat grass), some only browse (eat leaves), and others eat both. These data support this idea but also demonstrate a more complex understanding: when plant species were considered, the diets of monitored herbivores were more distinct than previously thought, demonstrating the partitioning of plant species within the grazer-browser spectrum.

10. Study the data for buffalo, a wild species, and cattle, a domesticated species. How could these data inform management of wild populations near areas with farming and/or ranching of domesticated animals?

Scientists should be able to determine if the wild animals and domesticated animals are eating the same species. If they aren't, then farmers or ranchers shouldn't have cause to worry about wild populations competing with domesticated animals for food sources and threats to wild populations from habitat restriction may be lower.

11. Note that the data presented above are from a single wet season. Why would it be important to run the experiment again during other seasons?

During the dry season, the grasses will not be as abundant or have as much nutritious new growth, so the animals will have to shift their diets somehow. The species' diets might begin to overlap more, or they might shift to other distinct diets.

APPLICATION QUESTIONS

12. Consider each of the following examples and identify the mechanism by which the resources, and thus the niche, are separated (refer to the explanations in the table on page 4).

Mechanism	Description/example
Niche partitioning by time (diurnal vs. nocturnal)	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	Pileated woodpeckers and yellow-bellied sapsuckers both consume resources from the same tree. Sapsuckers drill rows of little holes to eat the sap and insects in the sap, while pileated woodpeckers dig deep holes to find insects in the tree trunk.
Spatial partitioning (soil nutrients and moisture by space)	Prairie grasses have different length roots: smartweed roots reach to nearly 100 cm, Indian mallow roots reach to 70 cm, and bristly foxtail roots are a clump only about 20 cm deep.

13. Which of the following statements best describes resource 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 does niche partitioning promote biodiversity?

Niche partitioning can increase biodiversity by allowing more than one species access to a limited resource. By dividing up use of the resources in such a way that the species don't have to compete with one another, a greater number of species are able to survive.

RELATED RESOURCES

- HHMI Short Film *The Origin of Species: Lizards in an Evolutionary Tree*
- Lizard Evolution Virtual Lab
- Griffin, J.N., and Silliman, B.R. (2011). Resource Partitioning and Why It Matters. *Nature Education Knowledge* 3(10):49.
- http://www.livescience.com/13550-grazing-animals-shaped-human-evolution.html

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