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Vertical Zonation: Studying Ecological Patterns in the Rocky Intertidal Zone

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ABSTRACT Vertical zonation is a fascinating and well-studied ecological pattern that is readily observable in nature, and general aspects of it can be easily understood by fifth- and sixth-grade students. In this lesson, live animals can be used to engage student interest, and provide a simple yet effective means of teaching students about the importance of animal adaptations in determining an animal's distribution in the rocky intertidal zone. Knowledge of different animals' adaptations, combined with a basic knowledge of the physiological stresses faced by these animals that live in what is perhaps the world's harshest biome, enable the students to make predictions about where each of the animals might be found within the rocky intertidal zone.

KEYWORDS vertical zonation, adaptations, biome, niche, physiology

Ecologists find and study patterns in nature. One such pattern that occurs frequently involves the dominance or presence of certain species only in specific areas. This pattern can be attributed to a variety of environmental factors that prevent a species from establishing itself outside certain boundaries. The pattern is apparent in the Rocky Mountains, as when one ascends from the valley floor towards the jagged and seemingly desolate peaks. Lower desert vegetation on the valley floor gives way, with increasing elevation, to steppe vegetation, which, in turn, is replaced by coniferous trees, until alpine tundra is reached above the tree line. This vertical zonation in Rocky Mountain vegetation is generally attributed to environmental factors including temperature and moisture level. Nowhere is this pattern of vertical zonation more pronounced or seen in such a small area, however, than in the rocky intertidal zone. The vertical zonation in the rocky intertidal offers students the chance to see a well-researched and obvious pattern and easily investigate some of the factors that cause this pattern to occur in nature.

Vertical zonation in the rocky intertidal zone is evident from the occurrence of specific organisms within distinct bands. The main zones seen in the rocky intertidal zone were first characterized in a paper by Stephenson and Stephenson (1949). The upper and lower limits of the organism's occurrence coincide with horizontal tidal levels, forming four zones: the supratidal, high tidal, middle tidal, and low tidal. In this lesson, the supratidal zone is not discussed. In the Pacific Northwest, the high tidal zone is dominated by barnacles. Barnacles give way to mussels in the middle tidal zone; the lower reach of the mussel populations are established by predatory

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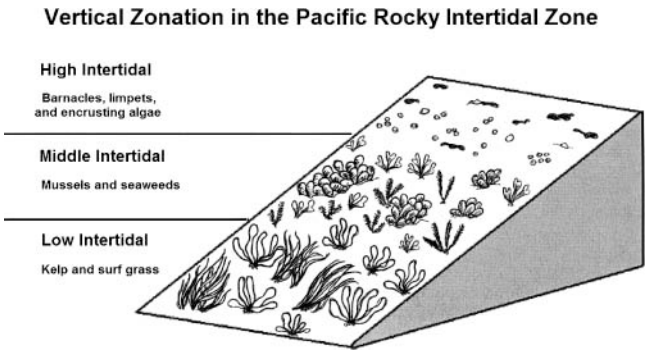

FIGURE 1 **Vertical zonation in the Pacific rocky intertidal zone, adapted from Stephenson and Stephenson (1949).**

sea stars (Levinton 1982). The low tidal zone is dominated by kelp and surf grass (see Figure 1). In the Atlantic rocky intertidal zone, there is less biodiversity, but the scheme of zonation is similar (see Figure 2).

In the rocky intertidal zone, as in the mountains, temperature and desiccation are physical factors contributing to the presence or dominance of specific organisms. Other factors affecting the distribution of species within the rocky intertidal zone include wave action; tidal range; an organism's mobility, competition, and predation; and the physiological tolerance of an organism to changes in temperature, salinity, and moisture levels (Levinton 1982). For example, predators such as sea stars need to remain moist in order to hunt and consume prey; hence, sea stars are restricted to lower tidal levels. This means that the sea stars' prey, such as mussels, can find refuge from the sea stars if they live in higher tidal levels. Therefore, the lower limit, or boundary, of the sea stars' prey is determined by the upper limit of the sea star population. This can cause a distinct line in the lower part of the rocky intertidal zone below which animals such as mussels are no longer present. In general, the upper limit of a species' distribution is controlled by physical variables and the lower

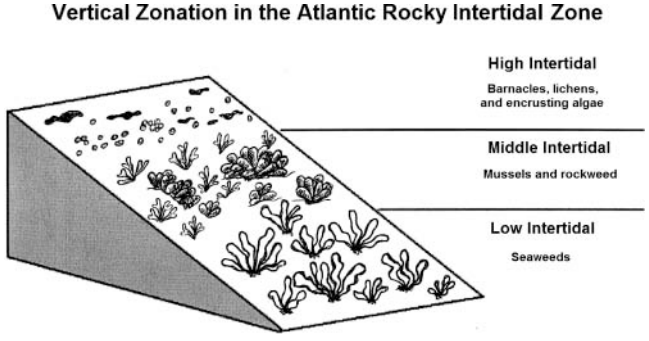

FIGURE 2 **Vertical zonation in the Atlantic rocky intertidal zone, adapted from Stephenson and Stephenson (1949).**

limit by biological variables. However, for the sake of simplicity, this lesson does not address the difference between what sets the upper and lower limits specifically. The factors affecting distributions are discussed more generally, in that they are listed and described as factors contributing to the overall pattern of vertical zonation. For additional information on this topic, a summary of these factors can be found at the U.K. Marine Special Areas of Conservations Web site (2001; see References).

This lesson is designed for fifth-grade students, but it could easily be modified for older grades as well. The factors leading to vertical zonation could be discussed in greater depth, and additional factors could be discussed as well. Inquiry activities could be designed as an extension to the concepts learned in the first two sessions. Ideally, this lesson could be done before, during, or after a trip to the rocky intertidal zone.

This lesson addresses science content standard C: life science in grades 5–8 from the *National Science Education Standards* (National Research Council 1996), which covers populations and ecosystems and diversity and adaptations of organisms. This lesson also addresses "Ocean Literacy: The Essential Principles and Fundamental Concepts" principle 5, concept f: ocean habitats are defined by environmental factors, and principle 5, concept h: tides, waves and predation cause vertical zonation patterns along the shore, influencing the distribution and diversity of organisms (National Geographic Society et al. 2006).

INTRODUCTION

Prior to this lesson, students should already have learned about food chains, so that they are familiar with the terms *predator*, *prey*, and *herbivore*. Ideally, they are also aware that different organisms interact with each other in different ways. This lesson emphasizes that physical factors, such as temperature and moisture levels, and interactions between different species, such as predation, can affect where a species lives. There is a lot of room for expanding within this lesson, as many important topics are addressed only briefly. Some ideas for expanding this lesson are included in "Extensions" below.

In this lesson, students identify the pattern of vertical zonation in the rocky intertidal zone using pictures demonstrating the pattern. They learn that different animals and plants (algae) live in the different zones.

Waves, tides, predation, and food availability are discussed as four factors that can determine in which zone a species might live.

This lesson can be conducted in two sessions. Between 30 min and 60 min are required for the first session. If students are familiar with simple marine food webs and ways in which waves and tides affect animals in the rocky intertidal zone, the first session should require 30 min. More time will be required if more details, such as desiccation or predation in the rocky intertidal zone, need to be explained or discussed. The second session requires approximately 60 min. After the first session, students should be able to recognize the general pattern of vertical zonation and the processes that lead to vertical zonation in the rocky intertidal. During the second session, students apply the information that they learned in the first session to make predictions about the likely location of various organisms in the rocky intertidal zone.

OBJECTIVES

At the end of this lesson, students will be able to explain some factors that lead to vertical zonation in the rocky intertidal zone, predict how these factors will affect a species' distribution in the rocky intertidal zone, and predict how a species' adaptations will affect its distribution in the rocky intertidal zone.

MATERIALS

Materials for Session 1

- Pictures of vertical zonation in the rocky intertidal zone
- Vertical zonation worksheet (see Figure 3)

Materials for Session 2

- Poster or drawing of a rocky intertidal zone (similar to Figure 1 or Figure 2)

Animal Adaptations	Environmental Conditions
High Tide Zone	High Tide Zone
Middle Tide Zone	Middle Tide Zone
Low Tide Zone	Low Tide Zone

FIGURE 3 **Student vertical zonation worksheet.**

Animal	Observations	In which zone do you think it might live?
Mussels		
Ochre sea star		
Hermit Crab		
Acorn Barnacle		
Nudibranch		
Whelk		
Limpet		

FIGURE 4 **Animal prediction worksheet.**

- Pictures of animals from the rocky intertidal zone, or live animals from the intertidal that are relatively easy to keep alive for a day (if available); depending on locality, these may include mussels, barnacles, whelks, sea stars, snails, littorines or periwinkles, chitons, hermit crabs, limpets, anemones attached to rocks, and nudibranchs. If two or more students are assigned to study the adaptations of the same animal, they can discuss their predictions together.
- Seawater in tubs, to hold the animals
- Animal prediction worksheet (see Figure 4), adjusted to list the animals (or animal pictures, if pictures are being used) brought to class
- One animal card for each student (Figure 5, for example)
- An information card for each live animal (Figure 6, for example)

PROCEDURE

Session 1: Some Factors Causing Vertical Zonation

1. Show pictures of vertical zonation in the intertidal. Point out the different species of organisms in each picture, and ask students if they can identify any patterns in the way that the different species are distributed in the pictures. Students may use words such as *layers* or *bands* to describe the pattern they see.

Animal Card: Front	Animal Card: Back
	Name of organism: Adaptations: Prediction: In which zone or zones would you most likely find this animal?

FIGURE 5 **Sample animal card (for student).**

2. Once students have pointed out the vertical pattern, define the term *zone* for them. A zone is a horizontal band within the rocky intertidal zone where one sees particular types of animals or algae but not others. Zones have upper and lower limits.
3. Ask the students why they think animals and plants might live within certain zones. Write a list of their ideas on the board.
4. Briefly discuss how waves, tides, predators, and food availability might affect plants and animals living in the rocky intertidal zone (see the U.K. Marine Special Areas of Conservations Web site; 2001). Review how an animal's surroundings might change from high tide to low tide. Talk about predators in the intertidal zone, such as sea stars, gulls, and whelks, and what they might eat. Also talk about food sources such as algae and plankton. Point out that most animals students will be observing are herbivores that get their food by grazing on plants or are filter feeders that obtain food by eating small animals *(zooplankton)* and plants (*phytoplankton*) that live in the water. It might be neither feasible nor practical to discuss all of these factors, so care should be taken in deciding which factors to address, depending on students' prior knowledge. When this lesson was presented to fifth-grade students, waves, tides (and desiccation), predators, and food availability were discussed. I showed pictures of huge waves crashing on the rocks to help the students understand the force to which these plants and animals may be exposed. When I asked the students what may have caused the patterns, their first answer always involved tides or desiccation, so they seemed to understand that concept. Students are always interested in the predators of the intertidal zone. However, based on assessment of student understanding following session 2, it seems that food availability is a more difficult concept to grasp, so more time should be spent on that aspect.

Pisaster
Eats mussels and snails
Needs to be moist to feed
Hard outer covering prevents it from drying out

FIGURE 6 **Sample information card (to place on table with live animal).**

5. Encourage students to visualize themselves as marine animals experiencing long periods of time in or out of the water, first pounded by waves, then baked by the sun. Have the students consider and list adaptations animals might have to enable them to survive in the various conditions discussed (e.g., shells to provide protection from predators, hiding under seaweed to prevent desiccation).

6. As a review, hand out the vertical zonation worksheet (Figure 3). The three zones are labeled. Have the students brainstorm, in small groups, the living conditions or environmental characteristics discussed in class that might affect the organisms living in each zone. Write these on the right side of the paper (under "Environmental Conditions"). Encourage students to include both biotic factors, such as food availability and predator presence, and abiotic factors, such as temperature and desiccation. When students are done, have them list adaptations that an animal may have to enable it to live in that zone. Students should list these on the left side of the paper (under "Animal Adaptations").

Session 2: Predicting Species Distribution in the Three Zones

1. To start the class, have a large poster, bulletin board, or chalk board ready with the three zones drawn and labeled on it: the high tide zone, middle tide zone, and low tide zone (a simple reproduction of the picture in Figure 1 or Figure 2, without the organisms drawn, will suffice). Review with students the abiotic and biotic factors affecting life in each zone and the adaptations that animals within each zone might have to enable them to survive there.
2. Show pictures of and describe three animals with which students might not be familiar, such as a peanut worm, a gooseneck barnacle, a brittle star, or a sea lemon nudibranch. Describe the characteristics of the animal, and have students suggest in which zone the animal most likely lives and why they think it might live there. Discuss the answers to make sure that students understand why certain animals are found in some zones but not others.
3. Hand out the animal prediction worksheet (Figure 4), and a different animal card (similar to the one in Figure 5) to each student. The list of species on the animal prediction worksheet should include all of the live species present in the classroom.
4. Place live organisms around the room in tubs, with an information card about each animal near its tub. (See Figure 6 for a sample information card). Three species per tub, with their corresponding information cards, works well. For example, one tub might contain mussels, a chiton, and a whelk. Information cards for a mussel, a chiton, and a whelk should be placed on the table next to the tub. If live animals are not available, pictures of animals also work. Alternatively, students can research their animal on the Internet to find information about its adaptations and physiological requirements; this would, however, require much more time.
5. Students move from table to table, make observations of each animal species, read the information card, and predict the zone(s) where the animal might live. Students write their observations and predictions on the animal prediction worksheet.
6. When students find the animal that matches their animal card, they need to fill out the back of their card with the information from the information card. This information will help students place their animal in the correct tidal zone. When the students have filled out their animal card, they take it to the poster or chalkboard and tape the card into the zone in which they think the animal belongs. Prepare extra copies of each animal card in case students think the animal might live in more than one zone.
7. When all the students have finished taping up their animal cards, assess the students' understanding by asking individuals why they think their animal belongs in a particular zone. Discuss the presence of predators. Have the sea star eat mussels that are placed in the low zone by pulling them off the board. Have a gull eat animals placed too high. Discuss tidal heights and the effects of desiccation. Crumple soft-bodied creatures that are in the high tide zone into a ball to demonstrate desiccation. Discuss factors that students might not have taken into consideration when placing their animals on the board, such as wave action and food availability.
8. Have students summarize what they learned from this activity by writing a short paragraph about what factors cause vertical zonation or how some animals are adapted to live in certain areas of the intertidal zone.

DISCUSSION

Although vertical zonation is a complex topic involving many different aspects of marine biology, students can understand its main ideas if the important concepts are emphasized. There are other factors besides those

discussed in this lesson that affect the zones in which an animal may live, such as the availability of larvae to settle and grow. However, the lesson should focus on how tides, wave action, predators, and food availability affect where an animal lives in the intertidal zone and how animals' specific adaptations enable them to live within the zones. This will help students make sense of the patterns they may have seen in the intertidal zone.

My students had already learned about marine food webs and marine animal adaptations before this lesson, which enabled me to move smoothly and relatively quickly through the discussions in the lesson. The lesson and activities may take longer if students are less familiar with marine food webs or at recognizing animal adaptations. Although it is not necessary for students to have covered all these topics before the lesson, a basic knowledge of food webs is important.

EXTENSIONS

1. This lesson could be modified to be used in the field at a rocky intertidal site.
   a. Students can observe the patterns of vertical zonation in the field. Session 1 may be done either in the field or in the classroom before the field trip.
   b. After the discussion, students head out to a rocky shore where vertical zonation is present to observe areas in each of the three zones. They identify animals in each of the zones and write observations about possible adaptations animals have in each zone that would enable them to survive there. They could note the presence of predators, location of the animal (under seaweed or rocks), and any predators or grazers caught in the act, such as sea stars eating mussels or isopods eating seaweed.
   c. Laminated information sheets and pictures should be provided for animals the students might encounter. This enables students to identify the animals and have access to information such as how the animals get food or what predators they might normally encounter.
   d. If time permits, an inquiry project could be conducted by measuring or observing one of the factors that might lead to vertical zonation for a species. Students could estimate the presence of a species of predator, quantify the difference in temperature between rocks in the low or high intertidal areas, or determine if there is an optimal size of rock to which barnacles will attach.
2. Observe how vertical zonation manifests itself with plants. This is best done on a field trip to the intertidal zone. If done in the classroom, collect plants from different zones and bring in specimens with the animals. These specimens could include small fucoids from the high intertidal, surf grasses and large-bladed kelps such as *Laminaria* from the low intertidal, encrusting and branching coralline algae, and green algae such as the sea lettuce *Ulva*. If possible, bring in rocks covered with algae so students can see how the algae modifies the habitat of animals living underneath the rocks. When students have completed the activity with the live animals, they can return to their desks and write observations about the algae. They can then make predictions about where in the intertidal the algae might be found and how the algae might affect other organisms within the same zone, such as by preventing desiccation and overheating and by providing shelter from predators.
3. Camouflage might be considered and discussed as an additional adaptation of animals in the rocky intertidal zone. If camouflage is to be discussed, it would be helpful to bring in some brown or gray rocks (or show pictures) from the high intertidal and some rocks covered with encrusting coralline algae common to the low intertidal to show that the background color also changes throughout the intertidal zone, so camouflage helps animals adapt to particular vertical zones. A brown, mossy chiton will be more camouflaged higher in the intertidal zone than a pinklined chiton, for example.

CONCLUSION

Vertical zonation is a great ecological concept to study for many reasons. It is easily observable and recognizable in the rocky intertidal zone and helps students understand some of the basic principles underlying the presence of organisms in different zones within the intertidal area. As the result of this lesson, students are able to identify physical factors that affect a species' distribution within the rocky intertidal zone. They can also identify adaptations that animals might need to live in the different zones within the rocky intertidal zone. Students will be able to use this knowledge to predict

where an animal might live based on the adaptations that the students observe in the specimens brought in to class. Studying these animals and their adaptations provides a fun and effective hands-on lesson that reaffirms the importance of studying organisms to learn about the natural world. These studies provide students with a sound foundation in basic ecological principles at a young age and encourage them to look for patterns in nature and to consider what natural processes may be responsible for observed patterns.

IDENTIFICATION GUIDES FOR THE PACIFIC NORTHWEST, NORTH ATLANTIC, AND GULF COAST

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