



# ZONATION visualizing patterns

*Students learn about basic ecological concepts  
and quantitative sampling techniques*

————— **Erin Baumgartner and Chela J. Zabin** —————

**T**he study of *zonation*, the distribution of plants and animals into distinct spatial areas, is a great way to introduce students to basic ecological concepts. Each zone is influenced by its physical characteristics and provides a unique habitat favoring the species that live there (Ricklefs 2001). These species in turn influence one another, so factors such as predation and competition also play a role in determining composition and spacing of different zones.

Students can conduct methodical, quantifying surveys of zones in areas as diverse as mudflats, beaches, forests, wetlands, and fields. Students collect data from these areas with field ecology techniques such as transects and quadrats, which allow students to estimate how many different kinds of organisms exist in an area or to describe relative abundance. This article describes a lesson sequence in which students gain an understanding about quantitative sampling techniques and how to effectively evaluate which methods work best for different surveys or in different types of areas.

### **Preparation**

In this activity, students learn about point-intercept transect, percent-estimate quadrats, and point-intercept quadrat quantitative sampling methods. Planning and conducting data collection to describe a field site requires students to practice basic sampling methods, including randomization and standardization. Students practice the sampling techniques in a familiar field area, such as a school lawn, before applying their learned techniques in one or more field sites off school grounds. Students compile and transcribe data collected from field sites into a visual model that helps demonstrate different zones. The creation of a visual map provides students with an opportunity to make hypotheses about causes of zonation related to basic ecological concepts such as biotic (living) and abiotic (nonliving) interactions controlling the distribution of species.

The lesson sequence described here can be accomplished within one month as a stand-alone unit or incorporated into a larger unit of study in ecology. The equipment needed

for surveying is easy to make or acquire and use. Building the skills and background knowledge needed to conduct data collection in the field takes five to eight 45- to 50-minute class periods of instruction including the practice work on school grounds or other familiar site. Planning (including site information and safety briefings) and conducting a field trip to collect data takes another three to four periods of instruction, and follow-up activities—including the zonation visualization activity—take two to five periods of instruction.

## Sampling techniques

### Transect lines

Students first learn about point-intercept transect, the most basic sampling technique to conduct in which researchers identify what living things or substrate are under each point at predetermined lengths along a line. Transect lines are long, heavyweight measuring tapes, and can be purchased commercially from companies for around \$50 or constructed from measuring tape weighted at each end. Simple low-cost transect lines can be constructed of rope marked at regular intervals with permanent ink or electrical tape.

Students can construct transect lines by measuring along the lines at a field site and marking every meter or other predetermined length that they want to sample. The technique for gathering data requires students to move along the line and record what they find under each point along the line. [Note: Recording data is discussed in more detail under “Developing field procedures,” later in this article.] This technique is good for quickly sampling a large area but can overlook information if the area is complex.

### Quadrats

Students next learn that quadrats are useful when sampling a complex area. Quadrats are usually square frames strung with a grid of intersecting lines (Figure 1) but can be empty round or square frames that enclose a known space. If the field site is a dry area, quadrats can even be made from cardboard frames cut to an appropriate size. Hula hoops work well for measuring percentage covered within a large area, and younger or special-needs students can record percentage visually by using data sheets with empty circles that can be colored as pie charts.

High-quality quadrats can be manufactured from PVC pipe and monofilament line (Figure 1). We construct our quadrats from four equal lengths of 1/2 inch diameter PVC pipe connected at the corners using elbow connectors and epoxy. We drill 5 holes in each side of the square and string monofilament line through these holes to form a grid with 25 intersecting points. These quadrats are waterproof and sink in water due to the holes drilled in the PVC.

Quadrats can be used in two ways. The first is to visually estimate percent cover of different organisms or substrate within the standard area framed by the quadrat at different points at the site (usually along a transect line). The second technique requires a quadrat with a grid; the point-intercept

method counts what is under each of the intersecting points of the quadrat grid at each location where the quadrat is set down. (The intersecting lines are also useful for the visual method, as the squares aid estimation.) Quadrats are best used in conjunction with transect lines. The measurements can be taken at predetermined points along the line. Some researchers also use a technique where quadrats are placed haphazardly by tossing and measuring where the frames land. Care should be taken when using this technique to ensure that no fragile organisms (or other researchers!) are struck by the tossed quadrat.

Before going out to any field site, our students practice the two quadrat methods by gathering data from life-sized photographs. We use a digital camera to photograph an area from the final study site where students will be collecting data. We edit the photograph to the size of the quadrat and add in different organisms at known proportions using Photoshop. Students use the printed and laminated “photoquads” to practice the percentage and point-intercept techniques and ask questions about how to use the techniques. If there are organisms that students need to be able to identify at the field site, photoquads also allow for practice of identification in conjunction with field guides or keys.

## Developing field procedures

Students are now ready to practice sampling in a simple, familiar area, such as the school lawn (Figure 2, p. xx). After trying each sampling technique, students should reflect on how techniques work, noting positive and negative aspects of each technique and considering which might be best to use in different kinds of areas. (Questioning strategies to help guide this discussion are included in Figure 3, p. xx). Students can then develop

**FIGURE 1**

**Student using a quadrat constructed from PVC and monofilament line to measure algal cover at Diamond Head Beach Park, Oahu.**



PHOTOS COURTESY OF ERIN BAUMGARTNER

and use a plan to collect data at the remote study site of interest, thinking about how best to use each method or a combination of methods to accurately gain the most information about the site. Students (and teachers) will face the same challenges ecologists face when planning how to sample an area.

The first thing to consider is the purpose of the survey. The sampling methods we have described focus primarily on substrate cover, rather than discrete numbers of individuals. Techniques for measuring numbers, particularly if organisms are sparse, may include band transects—recording all organisms within 1 m on either side of the line—or actual counts within a quadrat. Students can also consider the appropriate level of distinction to record organisms, either to type (grass, bush, tree) or to species. Students will need to decide if and how to record tiny objects, like small snails, that may make up a small percentage of the cover. Students might also want to consider how to measure and record nonliving factors in their study site, for example trash, dead plants or animals, sticks and leaf litter, or bare substrate such as rock, sand, or dirt.

Most field sites have some degree of vertical stratification. Students may also think about how and if to sample layers. What will they record if a blade of algae is lying over a snail, which is on a rock? The class must decide ahead of time to count only the top or bottom layer, or record everything. [Note: If quadrats are used, the work can be greatly multiplied, making counting everything in layers unrealistic.] Another logistical issue to consider is also related to three-dimensionality. What if the transect tape hits something tall, like a large rock, or a quadrat needs to be placed over an object that it cannot fit over or around, such as a tree? Considering these real-life field issues are opportunities for students to practice problem solving and standardize their experimental protocols.

### Visualizing zonation

Once students have learned and practiced sampling methods, considered possible challenges, and developed a protocol, students are introduced to the field site through an information briefing including maps and photographs of the site. In our class, students visited Diamond Head Beach Park (Figure 4, p. xx) on Oahu to survey an intertidal area and quantify different species of algae.

Upon returning to the classroom, students can use the data they collected at the remote study site to create a visual map describing zonation at the site. Our technique is to sketch a stylized site map of the area surveyed, including the transect lines, on an overhead transparency. Students determine relative percentages of different organisms or substrate types along the transect lines and record them at the appropriate place on the map using colored symbols (Figure 5, p. xx). If time and resources are limited, the zonation maps can also be made using data collected by students in the schoolyard.

For example, students ran transect lines perpendicular to the waterline in an intertidal area and quantified different

FIGURE 2

Students using transects and quadrats to sample the school courtyard.



types of algae. Although we try to identify individual species as much as possible, some taxa are difficult to identify to species, and may be identified only to genus, or even with a description like “turf.” Dominant species at Diamond Head Beach Park include *Sargassum echinocarpum*, *Padina australis*, *Ulva fasciata*, and multiple species of *Laurencia*. These easily identified genera (Magruder and Hunt 1979) made up the majority of cover at the Diamond Head Beach Park site on Oahu. Algal cover is easy to quantify using transects and quadrats, as well as zonation of algae within the Hawaiian intertidal area known to be influenced by a variety of factors (Smith 1992). Other sessile and easily quantified organisms found in the intertidal area such as barnacles and limpets can also be identified. Our maps used a brown *S* for *Sargassum*, a red *L* for *Laurencia*, a green *U* for *Ulva*, and a yellow *P* for *Padina*. These colors were chosen to be representative of the characteristic colors of each genus. The size of each symbol represented the relative percent cover and provided an overview of the pattern of algal cover of the area (Figure 5).

To place a stronger emphasis on quantitative data, an option is to have students record the percentage of each category along the transect line in a designated color. Data entry and analysis programs like Excel can also make it relatively easy to graph the different amounts of organisms and substrate. Recording and analyzing numeric data can take several class periods. If time is limited, students can consolidate several points along the transect line and calculate averages for a series of larger sections. These can still be used to visualize zonation patterns if the sections are an appropriate scale to the zones at the field site.

Whichever method is used, students can use their visual map to examine zonation and make hypotheses about causes. In our study of algal zonation, students noticed that the brown *S* symbols (*Sargassum*) were larger near the water, while the yellow *P* symbols (*Padina*) were larger farther up the shore, and the red *L* symbols (*Laurencia*) were only

### FIGURE 3

## Questioning strategies and example responses.

### Sampling techniques

How could we figure out how large the population of a species is in an area?

*Counting, but if there is a lot of something that may take a long time. We could estimate, but there should be a methodical way to do so, such as sampling.*

What are the pros and cons to each method?

*The point-intercept transect technique is quick and useful in a large, uniform area with large organisms. It overlooks a lot of information, and would not work well in a diverse area, though you can use it to decide where to put quadrats. The percent-cover quadrat technique is slower, but provides more information, allowing for every species you see. There is more error because it is an estimate. The point-intercept quadrat technique gathers more information than point-intercept transect, but can miss rare species if they are not under the point. It is very precise however: There is little room for error because you only count what is under the point.*

What are potential sources of error for each method?

*Point intercept transects and quadrats can overlook rare items that may never be under a point. Percent quadrats rely on estimation and yield “fuzzier” data. Mobile or cryptic things might be missed no matter which method we use. For example, students collecting data at Diamond Head noticed fish swimming out from under quadrats when they set them down.*

How can we reduce bias from our study?

*Randomize or choose methodical ways of sampling ahead of time. It is important not to choose the area that looks most interesting or diverse or because it has the most of our species of interest in it. Sometimes, areas must be eliminated due to logistic or safety reasons. We could not measure algae at Diamond Head all the way to the low tide line due to high waves.*

### Zonation

What patterns, if any, do you see when you look at the graphical representation of your data?

*Varies by area, but often things are more abundant close to water or in shade. Students may note that certain organisms are often found together. In addition to the algae zonation patterns we noted, we also found that barnacles and limpets were often living together in the Padina zone.*

What kinds of things might be causing these patterns?

*Varies by site, but may be due to various physical factors, presence of predators, or availability of resources like food or sunlight. We hypothesized that Laurencia would dry out very quickly compared to Padina, but Laurencia might have some defenses against predators that Padina does not have allowing it to grow in deeper water where there are more grazers.*

If you collected the data using different strategies, what were the differences and why?

*Quadrats present a more complete picture than transects. Percentage quadrats also record species such as barnacles that point-intercept may not if those species are small or rare.*

Did your study of zonation miss anything?

*Less abundant species might not have been recorded at all because they were more likely to not occur in areas where we put our quadrats. Also, depending on the methodology used, species that hid under objects and mobile species probably ran away before the quadrat could be set down.*

How could we test our hypotheses about the causes of zonation patterns?

*This question should engage students in scientific thinking about how to test their hypotheses, and can be incorporated into a project-based unit. As just one example, to test our hypothesis about relative desiccation tolerance of Laurencia and Padina we could collect samples of each, expose them to air, and weigh them hourly or daily to determine if the proportion of water lost is higher in Laurencia.*

found at the water line. Student use of the visual zonation model led them to develop a hypothesis about the ability of different algal species to resist desiccation or drying.

Hypothesizing about reasons for these patterns introduces students to ecological concepts such as predation, limiting factors, interconnectedness, and niches. The class hypothesized that algal zones were influenced by the relative amount of time they could tolerate exposure to sun and air. Other hypotheses related to algal zonation include predator preference for some algal types over others or competitive superiority of a species. Placing field trips into the framework of developing a study of and analyzing data related to zonation also pro-

vides perspective and follow-up to the field activities. Because many areas have some moderate zonation, this technique can be incorporated into most field sites.

### Assessment of student learning

Learning goals of this activity are for students to gain understanding about quantitative sampling techniques and to effectively evaluate which methods work best for different surveys or in different types of areas. We ask students to develop a table identifying pros and cons for point-intercept transects, percent-estimate quadrats, and point-intercept quadrats. The table also must describe an area in which

**FIGURE 4**  
**Collecting data at Diamond Head Beach Park, Oahu.**



each sampling method would be appropriate. Students demonstrate understanding by identifying strengths, weaknesses, and different types of sites where each strategy would be optimal. Further application of knowledge can be demonstrated by developing a plan for sampling the school grounds, and subsequent to that, an additional field site. To do so, students must demonstrate that they understand how the techniques work and effectively use them to quantify the coverage in an area.

Students should also be able to clearly describe zonation patterns in a field site and develop hypotheses explaining those patterns. Students demonstrate understanding by developing an effective visual map and describing zonation at their study site verbally or in writing. Their hypotheses should be clearly described and formulated. Because zonation is influenced by both abiotic and biotic factors, hypotheses that take these factors into account demonstrate understanding of ecological processes. In addition, by presenting multiple hypotheses for zonation patterns, students demonstrate that they are able to think critically by taking alternate explanations into account.

Providing students with an opportunity to conduct scientific work in a field setting is valuable, especially when the experience is connected to ongoing learning. Zonation mapping is an easy and

powerful way for students to put their field experience into a larger scientific context, while also providing a concrete example of ecological concepts that is much more relevant to students than an abstract text example could ever be. ■

*Erin Baumgartner (erinbaum@hawaii.edu) is a science teacher at the Education Laboratory School administered by the Curriculum Research & Development Group at the University of Hawaii, 1776 University Avenue, Honolulu, HI 96822; and Chela J. Zabin (zabinc@si.edu) is the Program Manager at the Smithsonian Environmental Research Center Romberg Tiburon Center for Environmental Studies, 3152 Paradise Drive, Tiburon, CA 94920.*

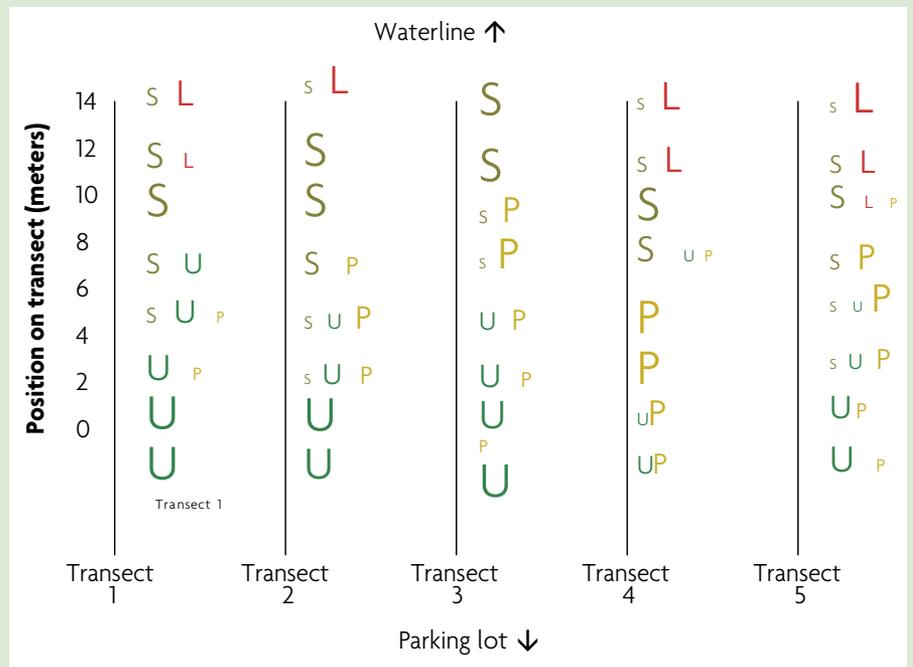
**Acknowledgment**

The authors would like to thank Kanesa Duncan for her suggestion of having elementary students use circular quadrats and pie-chart data sheets.

**References**

Magruder, W.H., and J.W.H. Hunt. 1979. *Seaweeds of Hawaii*. Honolulu, HI: The Oriental Publishing Company.  
 Ricklefs, R. 2001. *The economy of nature*. 5th ed. New York: W.H. Freeman.  
 Smith, C.M. 1992. Diversity in intertidal habitats: an assessment of the marine algae of select high islands in the Hawaiian archipelago. *Pacific Science* 46: 466–479.

**FIGURE 5**  
**Representative map of algal zonation patterns from student data collected at Diamond Head Beach Park on Oahu.**



L = *Laurencia sp.* S = *Sargassum echinocarpum* U = *Ulva reticulata* P = *Padina australis*. Size of symbol represents relative proportion of algae recorded at that location.