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Supplement: Description of OPIHI (Our Project In Hawaii's Intertidal) curriculum in three parts: (1) introduction to OPIHI intertidal species identification, (2) introduction to sampling, and (3) measuring abundances.

Introduction to OPIHI Intertidal Species Identification

The best way to learn to identify OPIHI organisms is to collect some intertidal algae and invertebrates and bring them back to the classroom (see “Conservation and Collection Information” and “Intertidal Animals in the Classroom” under Field Trips on website). We have complied a list of Key Species to refer to when looking for good representative organisms to collect. You can also refer to site-specific species lists (under “Data Sheets” in Field Trips on website) which list the most common species found at each intertidal site. Remember that the OPIHI program is set-up so you do not need any prior knowledge about the intertidal or intertidal organisms, thus you should not feel like you have to be an “expert” when identifying them. We encourage you to look through the books and identification cards with your students and allow them to conduct research and teach you about the diversity of different taxonomic groups. You and your students can learn together about the diversity of life between the tides.

At least one class day should be spent in class observing and identifying organisms before the first field trip. Demonstrate to your students how to handle organisms gently, and to only remove them from the water for limited periods of time. If you are going on multiple field trips to the same, you can have the students collect organisms for classroom observation on the first trip during their biodiversity search of the area. Organisms collected via the biodiversity search should be identified and recorded.

It is important that your students are aware of and are able to identify the common Potentially Hazardous Intertidal Organisms. These can be introduced by looking in books and discussing safe searching techniques, such as not putting fingers into crevices. You can also have your students research these organisms to develop their own field first aid kit (see “Tips for a Safe and Effective Field Trip” under Field Trips).

Taxonomic Groups

A good way to begin an OPIHI project is to organize students into teams responsible for studying specific taxonomic groups of organisms found in the intertidal zone, such as fish, echinoderms, or mollusks. During the first phase, students examine their assigned taxonomic group and develop questions by making observations and performing simple experiments to become more familiar with the organisms. These questions can then be answered through experimentations as well as library and internet research. Each group can then present what they discover about their taxonomic group to their colleagues, which provides accountability and helps build a learning community. This portion of the project can be shortened or eliminated depending upon your goals. For example, if you are focusing on a specific area, you may want to have students only focus their projects on organisms common to that site. Organizing your students into taxonomic groups is also a good way to introduce field notebooks.

If you will not be able to observe live organisms in class the student can still familiarize themselves with intertidal organisms by looking at photographs and field guides.

Student groups could still do library and internet research on their taxonomic groups to present to the class.

What to do with Live Organisms

Field Guide: You can have students develop their own personalized identification sheets by collecting the common species at your intertidal site and giving students a worksheet with the organisms' names, with space for students to write a description in the own words of the alga or animal and then draw a picture to remember the species. Students can note any observations made of the live animal's behavior. This identification sheet can be expanded by researching key characteristics and unique features of each species. These student-generated ID sheets can be used on subsequent field trips. (This field guide could also be developed in a similar way on the first field trip). (For more information on field guides – see "Field Guide Final Project" under Assessments on website)

Organism Observation: Have students observe a particular intertidal organism for approximately 5 minutes. During this time the students should note the organisms' size, color, texture, morphology, special features, and behavior and draw its' picture (See sample Worksheet on website). Students should observe both invertebrates and algae. Students can formulate one or more questions about their organisms that can be answered through observation and simple experimentation over the rest of the class period (see Taxonomic Groups day 2 on website for how guide students to ask answerable questions and develop a testable hypothesis). At the end of class, have students identify their organisms using the ID cards and books and share their findings with their colleagues. (Identification materials should not be given out until the end of the activity to prevent organisms descriptions from limiting student questions.)

Algae: It is especially important to have your students become familiar with and identify the macroalgal species at their intertidal site before the field trip. Most of the organisms under our transects and quadrats will be algae. You may choose to have the students learn about the differences between green, red, and brown algae and identify species as such. It's fun to wrap up an algae lesson by making algae pressings (See Algae and Algae Pressing on website).

Classification: Have students group all of the organisms you brought back to the classroom based on common characteristics. You can then teach them the scientific classifications of their groups – e.g. echinoderms and crustaceans. This can lead into a discussion of the scientific nomenclature system.

Web ID resources

Bishop Museum website: http://hbs.bishopmuseum.org/hbs1.html

University of Hawaii at Manoa's Algae Pages:

http://www.botany.hawaii.edu/reefalgae/default.htm
http://www.hawaii.edu/reefalgae/invasives/index.htm

General algae webpage: www.algaebase.org

General fish webpage: www.fisbase.org

An Introduction to Sampling: Jellybeans in a Jar

Concepts: probability, randomization, bias, average, and replication

Modified by Joanna Philippoff from lessons developed by Erin Baumgartner and Chela Zabin

Introduction:

Field ecology is a great way to introduce students to scientific methodology, as well as concepts like biodiversity, zonation, and invasion biology. It simply isn't possible to examine or count every organism in an area. Sampling is a powerful tool that can allow us to categorize an area, without counting everything. It would be time-consuming, frustrating, and impossible to count every single snail on a beach or flower in the forest. Sampling is the process by which organisms in small areas can be counted, or quantified, to estimate abundance over a larger area. The small areas, or samples, must be representative of the larger area for these estimates to be accurate. The more samples we look at, the more accurately we will be able to describe an area. This is why replication, or repeatedly sampling an area, is important. Using representative sections of an area to estimate the composition of a larger site can be a challenging concept. This activity was developed to help introduce students to sampling and enable them to carry out studies of species diversity and abundance.

Methodology:

One way to demonstrate how sampling works is through a variation on the old "guess how many beans are in the jar" game. Fill a large jar with jellybeans of different colors of known quantities (or other candy or nuts, a healthier alternative, which can be purchased in bulk at a candy store). For instance, 1 pound of red jellybeans, .5 pounds of green beans, and .25 pounds each of yellow beans and orange beans, is enough for one class of 25 students. Thoroughly mix the beans, and then have students each randomly remove ten beans from the jar. It is important to remind them not to pick favorites! One way to do this is to have the students just grab a handful and then count out ten; another alternative is to have them close their eyes while sampling. Record each student's sample on a table that everyone can view, and average the results from each color. Compare the average proportion of beans from the samples to the known proportion in the jar.

Sample data from student "collections" of jellybeans

Student	Red (.5)	Green (.25)	Yellow (.125)	Orange (.125)	Total
1	6	3	1	0	10
2	1	4	2	3	10
3	3	3	2	2	10
4	5	4	0	1	10
5	4	1	3	2	10
6	8	1	0	1	10
7	5	2	2	1	10
8	4	3	1	2	10
9	7	2	0	1	10
10	6	3	1	0	10
Average	4.9 (.49)	2.6 (.26)	1.2 (.12)	1.3 (.13)	10 (1)

The numbers in parentheses are the proportion of each jellybean color, both the original known (top row) and the deduced proportions through sampling (bottom row). Because the students took samples of 10, you can convert the average amount of each color into a proportion by moving the decimal to the left one place (see bottom row). The average adds up to 10, while the proportion adds up to 1. Percentages (not shown) would be calculated by converting the average amount by moving the decimal place once to the right (ie, the red average of 4.9 would be 49% red). Percentages add up to 100%. You can use both percentages and proportions when comparing the class data to the known quantities of colors.

Students will probably be amazed by how closely their averaged samples match the jar's known proportions, leading to a discussion of "Why does sampling work?" (Our favorite answer "it's like the sample is a miniature of the jar".)

Questioning strategies:

Can we count all individuals of a given species at a site? Why or why not?
This is a good introduction to the topic of sampling, as we cannot count every individual.

What does sampling mean to you?
Many students equate sampling with the small food samples given out at Costco and other grocery stores. This is a good comparison to ecological sampling. The food store may be trying to get you to buy an entire pizza by offering you a bite-sized morsel. As a consumer, you are assuming that the entire pizza will taste like the sample. In ecological sampling, we look at small portions of a community and assume these samples are representative of the entire area. The more you sample, the more accurately you will be able to describe the larger area. For instance, a pizza may have many different toppings. If you only sample it once, your small piece may only have one topping. If you did not know how many toppings were on the pizza, you would assume there was only one based on your sample. But, if you sampled the pizza many times, you would likely get a variety of toppings in your sample. The more we sample a site, the more accurately we will know the species composition of the site.

How many "species" of jellybeans are there in this jar?
This can lead into some good discussions about what species are: are red jellybeans with yellow speckles the same as solid red ones? Males and Females of the same species may look different, as do juveniles and adults. Or perhaps these speckled jellybeans represent a hybrid between the solid red and solid yellow jellybeans. Scientists have to agree beforehand to what level they want to make distinctions.

Before the class records their samples, have each student look at the sample in front of them. What can you tell me about the whole jar of jellybeans based on your sample?
Students will usually say you can tell how many colors there are, which ones are the most common and which the least, and actual mathematical ratios of colors.

What would happen if we only recorded the first several samples?
As more samples are added to the table, students will be able to see that many individual samples do not reflect the proportion of the jar very well. But when all the samples are averaged together, the proportion of jellybeans in the jar is evened out. Thus the more we sample, the more accurate our data. This demonstrates the power of replication. To illustrate the importance of taking many samples clearly, you can try taking an average of the first three samples. Usually this does not result in the same proportions as does the full data set.

You might ask students to think of reasons in nature that would cause individual samples to not reflect the population. For example, one sample might have been collected after a storm, or from an area where a tree had recently fallen.

What would happen if you chose your favorite beans when sampling?
This is the concept of bias, favoring some sample over another for some reason. It might be that more students prefer red jellybeans, and so they choose more red beans in their samples. This could throw off the results.

What are some other things that could cause bias in our samples?
Favorable sampling by scientists, like in the question above, or natural qualities of the organisms being sampled. For example, if some beans were larger, they might have been easier to grab. Or perhaps some were heavy and sank to the bottom of the jar, or some jellybeans were rounder and they rolled away. Another source of bias would be if each student took a different number of jellybeans. A good time to discuss this would be if a student accidentally got too few or too many when sampling the jar. Ask the class what they should do with this data. The class may decide to have the student take another sample, or close their eyes and randomly discard the extra candy. For the purposes of this activity, as long as the entire class agrees, the procedure is standardized, and does not introduce additional bias, it does not matter what they decide.

If students have problems grasping the idea of bias right away, you can redo the exercise and introduce bias on purpose to see how it affects the data. Two ways to do this would be to have the students select their favorite colored candies, which would throw off the calculated class proportions from the known quantities in the jar, or have three different sizes of jellybeans in the jar. Have the class decide if the different sizes represent different species or the same species at different stages in their life cycle. Perhaps the large jellybeans settle on top, leading the class to over-sampled them and thus conclude there are a larger proportion of them in the jar than there really is.

Rare Species
Place only one jellybean of a distinct color (ie. white) in your jar. The probability of this one jellybean showing up in any student's sample is very small. The white jellybean represents a rare species. Even after sampling the jar many times the white jellybean may not show up in anyone's sample. This demonstrates that in the field, even using the best sampling practices, you may not capture all of the species in an area, especially if they are rare.

M&M Variation:

Using an opaque bag of unopened candy, such as M&M's, ask the class to hypothesize about the proportion of different colors in the bag. Which color do they think will be the most abundant? the least? Why? Students will already have prior knowledge from eating common candies upon which to base their hypothesis. After recording the first few samples on a table everyone can see, ask the class if they would like to modify their hypothesis as they now have some knowledge about the contents of their M&M community. Upon completion of the activity, ask the class if they think the color proportions in their bag will be the same in other M&M's bags. The M&M bag is itself a sample of all the M&M's produced at the factory. While the students sampled one bag many times, they only sampled the "entire population" of M&M's produced at the factory once. Thus, the class activity was really sub-sampling a sample.

Your class may be curious how close the color proportions in their sample, the class bag of M&M's, approximate the proportions produced by the M&M's factory. From the M&M's website the proportions of each color produced (the "entire population") in plain milk chocolate M&M's are as follows: 13% Brown, 14% Yellow, 13% Red, 24% Blue, 20% Orange, 16% Green**. Chance factors involving the machines used by the manufacturer introduce random variation into the different bags produced. Some bags will have a distribution of colors that is close to the proportions produced by the factory, while others will be further away. Doing this activity again (replication) with different bags of M&M's and averaging the color proportions would allow your class to better approximate the proportions produced in the factory.

**Proportions differ for each type of M&M's candy (ie. peanut, dark chocolate, crispy), so check the M&M's website if you're using a different product.

Measuring Abundance: Transects and Quadrats

Concepts: estimation, percentage, error and zonation

Modified by Joanna Philippoff and Erin Cox from lessons developed by Erin Baumgartner and Chela Zabin

Introduction:

Transects and quadrats are two ecological tools that allow us to quantify the relative abundance of organisms in an area. To track changes over time, it is important to be able to quantify changes in abundance. Also, learning these techniques will give students the tools necessary to ask their own ecological questions and make comparisons among sites. A transect line is any line, marked at regular intervals, that is easy to use in the field. Transect lines can be purchased commercially, made from measuring tape or rope marked off at regular intervals. A quadrat is a framed area. A frame can be made using PVC pipes, wire hangers bent into squares, hula-hoops, wooden dowels or even cardboard. Use monofilament or string to section off the quadrat into a set number of squares or intercepts.

Point-intercept along a transect line: The simplest ecological sampling method is point intercept. You can lay the transect line across the classroom and record what is directly under each meter or half meter mark on the line (e.g. table, floor, backpack, book, pencil, student). This technique is good for sampling a very large area relatively quickly, but as students often point out, it can miss a lot of information if the area is complex. The use of quadrats can help achieve additional levels of complexity.

Visual estimate within a quadrat: Place a quadrat along pre-determined points along a transect line and have students estimate and record what percent each item takes up within the frame (e.g. 75% species A, 25% species B). The quadrat divisions can also be used to estimate what is in each of the smaller squares (e.g. 12 squares species A, 5 squares species B, 0.5 squares species C, etc.). Organisms that take up very little area can be recorded as <1% or <0.5 squares.

Point-intercept within the quadrat: Place a quadrat with intersecting lines along pre-determined points on the transect line (usually the same points as used for the visual estimate) and record what is underneath each intersection within the quadrat frame. This method is similar to that used on the transect, but there are multiple intersections within the square frame to be counted.

Photoquadrats:
Students can compare the two quadrat methods by using photo quadrats: photographs of an area from the study site sized to fit the quadrat frame. By trying the techniques within the classroom setting, they have a chance to practice and ask questions about how to employ the techniques. This also allows the students to practice identifying the organisms they will find at the study site using ID cards or reference books in the classroom.

Sample Lesson to Introduce Transects and Quadrats: Sweet Species

One way to introduce transects and quadrats is through the use of candy “sweet species”. Buy an assortment of candy (or cut up different colored index cards), of various sizes and shapes, to represent different species at your monitoring site. This activity works best if the sweet species are substantial in size or grouped in “snack bags” that candy companies sell at Halloween.

Small candy will be hard to monitor, just as small species in the field are harder to monitor. Throw the candy on the classroom floor and ask the students how they would go about monitoring the species in their classroom study site.

Learning How to Lay Transects:
Divide the class into groups and give each group a transect. Without giving any additional information, ask each group to lay out their transect in a location to best monitor the sweet species. You will most likely get a spider-web of transects laid out over the study site. Point out that where transects cross, organisms or candy at the intersections will be recorded multiple times, falsely increasing their perceived abundance. To prevent this, the transects should be laid parallel to each other (an equal distance apart).

Special considerations at your study site will determine how you place the transects in the field. For instance, in the intertidal some species cluster in the high intertidal while others cluster in the low intertidal, creating different ecological zones that lie in bands along the coast. This means we need to lay our transects perpendicular to the shoreline to stratify our samples and sample appropriately across all the spatial scales of the intertidal.

You can demonstrate the concept of stratified sampling by using different colors of jellybeans layered in a clear jar. If your class were to sample jellybeans from the jar the same way the students sampled in the Jellybean Lesson, they would miss the species towards the bottom of the jar and overestimate the abundance of species on the top. Laying the transects perpendicularly in the intertidal is analogous to laying a transect through the jar of jellybeans, allowing us to sample from all the species “layers”. You can replicate this with your sweet species in your classroom. Determine where the beach and deep ocean lie in relation to your classroom study site and place different candy species in different bands or zones parallel to your classroom coastline. In the field, some intertidal species are present in many or all of the different intertidal zones, while others favor either the high or low intertidal.

Some other things to standardize when learning to lay transects that you can have your students discuss:

- “0” marks on transects should all be in same direction (into water, so turning mechanism of transect lays out of water to prolong life of transect)
- Transects should all have the same side of the tape facing up (scientists, and thus OPIHI, follow the metric system).

Demonstrating the Methods:
Have two students go along one of the transects. Record what is under each meter or half meter (depending on the size of your classroom) on a table everyone can see. Since your class is omnipotent and can see all the sweet species at their study site, your students can answer a lot of questions that would be impossible to answer in the field where the species will be a little more camouflaged.

- Did we get all of the organisms that are in the intertidal?
- Look around – are some organisms more common than others? Do you think the data from our transect reflects this?

Using quadrats may solve some of the problems that occur when just using a transect. As a class, decide where to place the quadrat in relation to the transect. It should not matter where the quadrat is placed as long as the placement is the same each time among all the groups.

For instance, always place the quadrat right over the transect point, which is easy to remember although the transect tape might obscure some organisms, or always place the (e.g. bottom left) corner of the quadrat over the transect point. Practice once as a class with two volunteers using both quadrat methods and recording the results on the board before having all the groups try both the transect and each quadrat method to monitor the sweet species.

"Tricky" Sweet Species:
Try to include two candies of the same shape, such as traditional silver Hershey kisses and purple colored dark chocolate kisses, or use both light and dark pink colored paper cards in the same shape. When recording species you can ask the students if purple kisses are the same species as silver kisses, or are if they are the males and females of the same species. As long as the class agrees and records the data in the same way, it does not matter how many species the candy represents. This is true in the class or in the field.

Practice makes Perfect: Courtyard Sampling
The next step is to have students practice all of the techniques in a relatively simple area, such as the school lawn or garden. Have the class decide the best way to lay the transects, determine how long they should be, and how often they should sample (ie. every meter or half meter) to most accurately monitor the site. Students should determine how specific their designations will be as a class before starting the activity so everyone records the same type of data. For instance will they differentiate between dirt and sand? Different types of grasses? Ask what would happen it they didn't decide on these guidelines before monitoring an area. As they try out each technique they can reflect on how each technique works in this setting, and think about how best to use them alone or in combination to accurately and efficiently gain the most information about an area. They may consider which techniques might be best to use in different kinds of areas. Finally, they can plan which technique or combination of techniques they might use to quantify an area, and then employ their plan in the field.

Lastly, before you go on your first monitoring field trip, it is helpful to practice the quadrat methods on photoquadrats, life-sized photographs sizes to fit the dimensions of your class's quadrats. This is especially important if you are monitoring an environment where students may be unfamiliar with many of the organisms they will encounter, such as the intertidal. Photoquadrats allow students to practice their quadrat methodology and species identification skills. As with the courtyard sampling, students can reflect on how well each quadrat sampling method works at capturing the organisms in the photographs. See the Photoquadrat lesson for more details.

Questioning Strategies:

How could we figure out how large the population of a species is in an area?
Counting, or making a list of species, but if there is a lot of something that may take a very long time. We could estimate, but there should be a methodical way to do so -- such as sampling.

What are the limitations of a list of species?
We won't know how many of each species. We could count and identify all of the species - but what if there is a lot of one species in an area? Or what about colonial species, like sponges, or species where it is difficult to determine what an individual organism is, as in some algal

species? What is the meaning of one sponge? Is one tiny sponge the same as one huge sponge?

What is monitoring? What do we need to know at a site to monitor it?
Monitoring is seeing how things change with time. To monitor a site we need to know the number of species at a site and species abundance, or how many of each species are present. If we always use the same methods to monitor a site, we can not only track changes in species over time but be able to compare different sites as long as both locations were monitored the same way.

What are the pros and cons to each sampling method?

- *Point-intercept transect is very quick and useful for sampling a very large, relatively uniform area, but it misses a lot of information. It would not work well in a finely grained, heterogeneous area.*
- *Percent cover within quadrats is a little slower, but you get more information. It allows you to account for every species present in a quadrat, but there is some uncertainty and a larger degree of error because you are estimating.*
- *Point-intercept quadrat gathers more information than point-intercept along a transect line, but it can miss species that aren't very abundant if they are not under a point. However, it is very accurate, easy to replicate, and there is not much room for error as you only count what is under the point.*

What are potential sources of error for each method?
Point intercept transects and quadrats miss out on rare items, because they may never be under a point. Percent quadrats rely on estimation, so they provide more fuzzy data. Things living under rocks or leaf litter or highly mobile things might be missed no matter which method we use.

How can we reduce bias from our study?
Randomize our sites for monitoring or choose methodical ways of sampling ahead of time. It is important, although sometimes difficult, not to choose an area that looks most interesting or diverse. Sometimes sites must be eliminated due to logistical or safety reasons.

How to answer the students' most popular question:
What do I write on my data sheet if a snail is on top of an urchin who is on top of an alga that is growing on rock?
When monitoring the intertidal in OPIHI, we only record what is on the surface layer, the snail in this case. Thus, when you are using the percent cover within quadrat method, each quadrat's data should add up to 100%. In the point-intercept quadrat method, the students should have a data point for each intercept (e.g. 25). Recording all the "layers" would cause the total percent cover to exceed 100 and total points to exceed 25. Counting only the surface layer makes it easy for the students to quickly double-check their data sheets. In OPIHI, we record all organisms as well as bare substrate, such as rock or sand, but not dead or transient objects like rubbish, driftwood, or water.

If you would like your students to practice taking data using other methods, you can have them record all of the “layers” under each point (in this case the snail, urchin, alga, and rock) or only those organisms on the primary substrate, in this case the alga.

In the Field:
If you only have a limited time to study a site, you may have to limit which methods you use to collect data in the field. The quadrat methods take much more time than the point-intersect transect method. We encourage you to teach all three sampling methods to your students in the classroom so they can learn about the pros and cons of each. However, due to time constraints, you may have to modify your data collection methods in the field. You can choose to only use one quadrat method (the “squares” method of percent cover with quadrats, for instance). You may choose to place your quadrats every other meter, or more, apart – this is acceptable as long as the distance between each of the quadrats is standardized. **If you plan to monitor a site over time, it is important that you use the same modifications every year.**