An Introduction to Sampling: Jellybeans in a Jar

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

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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, that 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.