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Assessing and documenting campus plant diversity to increase students' connections with nature

Kimberly M. Kellett

Perimeter College at Georgia State University, Life and Earth Sciences, 2101 Womack Road, Dunwoody, GA 30338, USA

Abstract

Spending time in nature has been shown to reduce stress, but students lead busy lives with little time spent outdoors and are increasingly disconnected with the natural world around them. This series of lab activities is designed to address common learning objectives of Introductory Biology classes while spending time outside on campus and becoming familiar with species they see every day. As a result of these activities, students can contribute long-term data sets on campus plant community diversity. Students do not need any previous experience with plant identification or ecological sampling. These labs are designed for non-majors Biology students but could be modified for majors. They do not require any specialized equipment. Students will spend time outside on campus conducting assessments of species richness and Simpson's Diversity Index. They will also use data to construct graphs and test simple predictions. Students who complete these labs will gain a familiarity with basic terms associated with plant identification and learn to recognize common campus plant species.

Keywords: Biodiversity, Plant biology, Ecology, Graphing, Species Richness, Data Analysis

Link to Supplemental Materials: https://doi.org/10.37590/able.v44.sup13

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Correspondence to: Kimmy Kellett, kkellett@gsu.edu

INTRODUCTION

Natural areas on campus provide a wealth of opportunities for students to study diverse organisms and ecological relationships, de-stress with time outside, and help promote healthy local ecosystems. However, traditional Introductory Biology labs are often spent completely indoors, working with lab-grown organisms or examining preserved specimens, with little connection to campus biodiversity. The activities presented here fulfill common learning objectives of Introductory Biology II labs while allowing students to spend time in nature, learn about local plants, and contribute to resources that can be used by future students and campus community members. Learning objectives addressed by these lab activities include: 1. Explaining the importance of assessing biological diversity of communities; 2. Measuring and interpreting species richness and Simpson's Diversity Index for a plant community; 3. Identifying basic leaf arrangements and anatomical features;4. Recognizing and describing common local plant species; and 5. Constructing and interpreting graphs.

The lab activities presented here are designed for first- or second-year students in Introductory Biology courses and are most appropriate for students who are not majoring in Biology. However, they can easily be modified to better suit Biology majors (see "potential extensions" under Notes for Instructor). These activities can also be used in Environmental Science courses or any course in which assessing plant diversity is a relevant objective. Each lab activity described takes one standard lab period (about two and a half hours) to complete and instructors can choose to use either or both activities in their courses. No previous knowledge in plant identification is required, but it is helpful if the instructor is familiar with some of the most common plants in the sampling area. No lab set-up is required, but instructors should plan to spend an hour or so to find an area of campus where these activities would work well and decide on a sampling plan that will work best for that area.

STUDENT OUTLINE

Activity I: Assessing Species Richness of a Plant Community

Objectives

Explain what species richness is and know how to assess species richness of a plant community
Construct and interpret a species accumulation curve
Discern plant species from one another using reliable identification traits
Identify/define basic leaf arrangements and anatomy

Introduction

The term **species richness** means the number of species in a particular ecological community. It is a common metric that scientists use to assess the general health of a community. Having more species in a community helps ensure it can remain in balance even if one species declines or goes extinct, as there will be other species to fulfill the role, or niche, of the extinct species. Think of an ecosystem as a company that has many different employees doing different jobs if one employee gets sick and can't work, there are likely some others who can take over the roles of the sick employee. However, if it is a smaller company with just a few employees, one absent employee can seriously disrupt the ability of that company to perform. Like a large, well-staffed company, ecosystems with higher numbers of species are better able to recover from environmental stress and maintain a functional food web. Measuring biodiversity is therefore critical in assessing the health of biological communities within ecosystems (Cardinale et al. 2006). Scientists can compare species richness among similar communities or assess richness on a regular basis to better understand ecological health and how it may change over time.

In this lab, you will measure the species richness of a plant community on campus. It would be extremely time consuming to examine and count every single plant in the community to determine species richness, so we will rely on combing samples from multiple students or student pairs to construct a **species accumulation curve.** This type of graph (Figure 1) displays the number of different species found in the number of samples collected. As more samples are collected, we should see the number of species level off, as there will be duplicates of each species collected in each sample. The "leveling off" of the graph is similar to reaching an asymptote (if you don't remember this word from math classes, don't worry) and indicates that our sampling efforts were accurately able to capture species richness of the area (Ugland et al. 2003). Community A in Figure 1 demonstrates a well-sampled community. If our species accumulation curve does NOT level off, such as the curve for Community B in Figure 1, it indicates that we may need to do more thorough sampling to accurately measure richness.

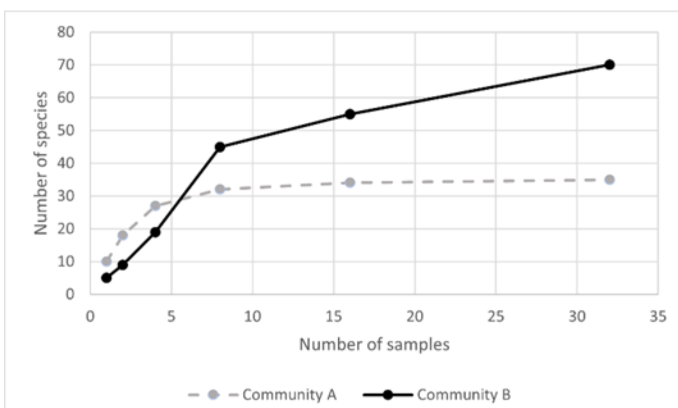

Figure 1. Species accumulation curves of two communities. We can be confident that species richness of Community A is about 35, while Community B may require more sampling.

Measuring species richness does NOT require you to identify species by name. You only must differentiate species from one another. The best way to differentiate among various plant species is by looking at their leaves, since reproductive parts such as flowers may not be visible at any given time. Leaves can change in color, size, and even texture as plants age or are exposed to different light or nutrient levels. However, the shape, leaf margins (what the edges of the leaf look like), and leaf arrangement on the stem are relatively reliable characteristics to use for differentiating among plant species as they remain consistent over changes in environment and time. Figure 2 shows common leaf arrangements on a stem, and your instructor may share more information or images.

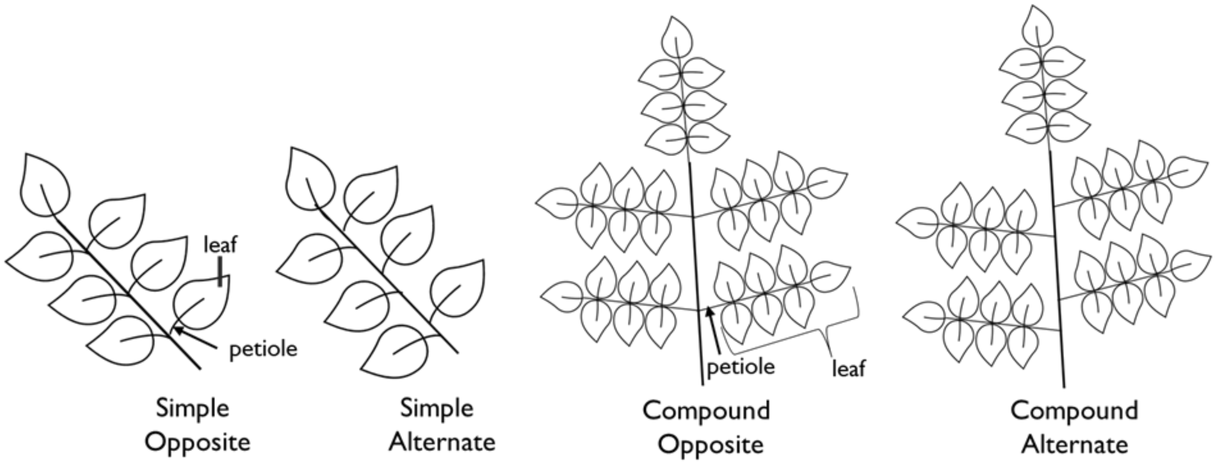

Figure 2. Four different leaf arrangements. Simple leaves are each attached to the stem with a petiole, while each compound leaf consists of multiple leaflets attached by a single petiole.

Procedure

Note: as you work on this procedure, you will complete the accompanying worksheet titled "Assessing Species Richness of a Plant Community." Complete the "Background & Predictions" section of this worksheet before beginning this procedure.

1. After your instructor has shown you the collection area and given you a collection bag, spend seven minutes observing the area quietly and record your observations and reflections in the space provided on the worksheet (under "Introduction to sampling area and reflections."

2. Spend ten minutes collecting leaf samples from as many DIFFERENT plants as you can find in the area. Make sure each sample includes at least THREE leaves.

3. After the collection period is over, empty your collection bag and make piles of samples. Each pile should contain only one species. (It will be very likely that each pile only has 1 sample in it but check closely for duplicates!)

4. After you have established your piles, complete Row 1 of Table 1 on your worksheet in the "Results & Conclusions" section. The number of samples is the total number of clippings you collected (Example: if you cut samples from 10 plants, then you have 10 samples.) The number of species is the number of piles you have (Example: if you cut samples from 10 different plants, but two of them belong to the same species, then you have 9 species).

5. When everyone has completed step 4, combine your samples with the person or pair nearest to you and establish separate piles of individual species again. Make sure you look closely for duplicates, as it is likely that some of the samples you and your new group member(s) collected belong to the same species.

6. After everyone in the group is satisfied with the new piles, complete the Row 2 of Table 1. For number of samples, just add the number of samples you listed in Row 1 to the number your new group member(s) listed. For number of species, record the number of piles you now have (hint: this number *should* be lower than number of samples, unless you have found no duplicate species)

7. After all groups have completed step 6, repeat steps 5 and 6 by combining piles with another nearby group, but this time complete Row 3 of data in your table. *A good way to approach combining samples as group size increases is to leave piles from one group in place and have pairs of people take piles from the other group and look for their "match" in the stationary group. If no "match" is found, establish a new pile. Double check for duplicates when you are done combining.*

8. Continue this process of combining samples and recording data in Table 1 until samples from the entire class have

been combined into piles of species.

9. Use the data in Table 1 to create a graph. Then, complete the questions remaining on your worksheet. (Hint: as you complete the "Plant Terminology & Traits" section, take photos of some of the plant samples you use demonstrating different leaf arrangements. You may use these to study later on.)

10. At the end of lab, please help clean up the plant samples and dispose of them in a compost bin or outdoor area.

Activity II: Estimating Simpson's Diversity Index of a Plant Community

Objectives

Explain what a diversity index is and how it differs from species richness
Use transect sampling and the Seek app to assess diversity of a plant community
Calculate Simpson's Diversity Index for a data set
Recognize and describe the most common plant species in the campus greenspace

Introduction

Species Richness, which you assessed last week, is an important aspect of biological diversity. However, species richness provides no information on evenness, which is the relative abundance of each species in a community. For example, imagine you ordered two pizzas with mushrooms, peppers, pepperoni, and olives and the following two pizzas were delivered. Which pizza best fulfills your order?

Pizza 1: 27 mushrooms, 5 pepperonis, 2 peppers, 1 olive
Pizza 2: 9 mushrooms, 10 pepperonis, 8 peppers, 8 olives

Although both pizzas have the 4 topping you asked for, Pizza 2 best fulfills the order. Pizza 1 is dominated by mushrooms and you would be very unlikely to get an olive or pepper on any individual slice of it, while Pizza 2 has a relatively EVEN distribution of toppings! When we talk about the evenness of species in a community, the idea is similar to pizza toppings. A community that is dominated by one or two species is not as diverse as a community that has a relatively equal number of all species, even if both have the same species richness.

Diversity indices, such as **Simpson's Diversity Index**, provide a single metric that accounts for both species richness and evenness. The formula for Simpson's Diversity Index is shown below. Although it may look complicated, it does not involve anything more than basic arithmetic. We will break the formula down piece by piece later in this lab to calculate Simpson's Diversity Index for a plant community on our campus.

$$D = 1 - \frac{\sum n(n-1)}{N(N-1)}$$

Figure 3. The formula for Simpson's Diversity Index (D). N is the total number of individuals in the sample, while n is the number of individuals within each species.

This formula will always result in an answer somewhere between 0 and 1. Communities in which individuals are distributed completely evenly (ie. there is the same number of every species) will end up with a value of 1. Therefore, communities with index values closer to 1 have higher diversity than those closer to 0.

It is usually unfeasible to count every organism in a habitat, so scientists rely on various sampling methods to collect the data they need to estimate diversity. For this lab we will use a method called **transect sampling,** which involves laying linear transects (tape measures or similar) at random points along the ground and identifying all plants found along each transect. You will use an app called Seek to help with plant identification. We can then compare diversity among transects and calculate average Simpson's Index for the area. We will also test a prediction about the relationship between Simpson's Diversity Index and Species Richness.

Procedure

Note: As you work on the procedure, you will complete the worksheet titled "Estimating Simpson's Diversity Index of a Plant Community." Answer the questions in the "Background and Predictions" section of the worksheet before beginning this procedure.

1. As a class, lay a 25m tape on the ground across the edge of the sampling area. Then, your instructor will use a random number generator to establish the starting point of each group's transect, which will be somewhere along the initial 25m transect.

2. After you are assigned your starting point, lay your group's measuring tape perpendicular to the initial tape beginning at the assigned starting point and extending 5m into the plant community (see Figure 4).

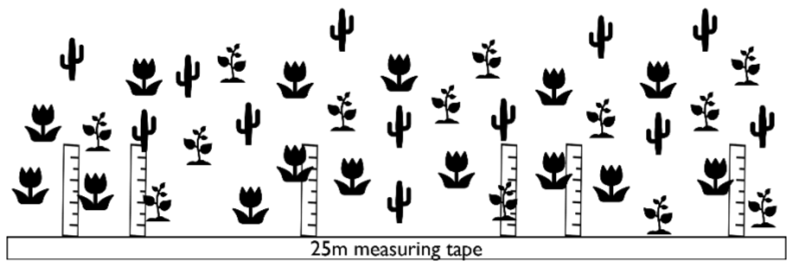

Figure 4. Sampling area with six student group transects extending from random points along an initial 25m transect. Note: this diagram is not to scale.

3. Record all the species that are touching or within 5 cm of the transect tape on either side to complete Table 1 in your worksheet. Use Seek to identify the plants to at least the level of genus. *For example, if I found a shoot of green brier (Smilax sp.) at 0.25 m and wild muscadine vine (Vitis rotundifolia) growing along the transect from 0.4 m to 1.2 m, I would record green briar in the first row of data and wild muscadine in the first 3 rows.* <u>*Before starting this step, please read step 4, as you will work on these steps simultaneously.*</u>

4. As you identify species in your transect, complete Table 2 on your worksheet for any species you find more than once. Your descriptions should include leaf arrangement and anatomy terms that you learned last week. As you become familiar with plants, try to rely less on Seek and practice identifying common species on your own.

5. Using the data you collected from your transect, complete Table 3 in the "Results and Conclusions" section of the worksheet. Calculate Species Richness as well as Simpson's Diversity Index.

6. Add your results to the class data table (your instructor will tell you where to find this).

7. After data from all groups has been collected, create a graph of Species Richness vs. Species Diversity Index to test the prediction you made at the beginning of the lab.

8. Answer the remaining questions on your worksheet.

MATERIALS

For Activity I: 16-24 collection bags (these can be plastic grocery bags or similar), one pair of standard garden clippers or heavy-duty scissors for each student, clipboard for each student (optional, but makes writing outdoors much easier), flags or flagging if you need to mark the sampling area, student worksheet handouts (see supplementary material).

For Activity II: One long (at least 25m) measuring tape plus one measuring tape (at least 5m) *per student group*, clipboard for each student (optional), each student group needs *at least* one phone or tablet with the Seek app (https://www.inaturalist.org/pages/seek_app) installed and access to internet (if multiple students have access to the app, it will help data collection proceed more quickly), student worksheet handouts (see supplementary material).

Optional: If instructors want to archive student data for future semesters (this can be useful in case of uncooperative weather conditions limiting time outside or for students to make comparisons among years), establish a long-term campus data set, or share data among students, they should also construct a Google sheet workbook that suits their individual needs.

NOTES FOR THE INSTRUCTOR

Activity I: The supplemental materials include the handouts/worksheets for both activities. Activity 1 is titled "Assessing Species Richness of a Plant Community."

Lab Preparation: Before you try this lab, you should scout campus to find an area suitable for this activity. It does not have to be a large area but should not be landscaped and should contain a variety of plant species with leaves that are within reach of students (lots of herbaceous growth makes idea habitat for this activity while older forests with little undergrowth are difficult to sample). Avoid areas that contain rare or threatened plants. It is ok if the area is "weedy" or contains many invasive species. If the potential area is large, you may want to mark a sampling area for your students using flags or flagging tape. The sampling area should be small enough so that students are able to collect samples from all or almost all species in the area. For very diverse habitats the sampling area may be relatively small, and for less diverse habitats the area can be larger. Closely examine the area for Poison Ivy or other "don't touch" plants and flag them. Decide whether you want your students to sample ALL plants including mosses, ferns, gymnosperms, monocots & dicots, or limit them to dicots (this is useful in areas with high plant diversity). If these are not terms your students have learned, you can tell them "no grasses, trees with needles, ferns, or moss."

During the lab: It is easiest if you start this activity by handing out 16 collection bags to your class (students can collect samples individually or in pairs) so that each time they combine samples, they can simply pair up with another group. However, if you'd prefer all students to collect in pairs, you can start with any even number of sample bags, just note that combining piles will require three groups to combine at some point (rather than two each time). Before collection, make sure students understand that they should collect at least three leaves from each plant. You may want to review what a leaf is and discuss simple leaves versus compound leaves (if these are not terms your students usually learn, then leave it out. The species richness activity tends to work fine as long as students are not just collecting single leaves or single leaflets.) Tell students not to sample very small plants that will be heavily impacted by leaf removal. If there are toxic plants, such as Poison Ivy, in the sampling area instruct students to avoid touching and collecting these plants. If the area you are sampling is large, you may want to space students out at different starting points for their collection to ensure the entire area is sampled. After collection, as students sort their samples into piles, you should walk around and "check" their work. Remind students that plants of different sizes/ages can have some variation in leaf size/color/texture but encourage them to decide in their groups whether they think samples are the same or different rather than relying on your opinion/expertise. It is OK if they and/or you get a few samples "wrong" – it will not ultimately impact the general outcome of the activity!

Potential extensions for Activity I: If you have more time or several sections of students, consider using multiple sampling areas around campus. This way, there is less impact from leaf removal in one area and students can compare Species Richness among different areas (for example, different habitats) to test hypotheses they develop. You can also pair plant data with diversity data your class (or other classes) have collected on insects, birds etc. in the same areas to test whether plant diversity correlates with animal diversity.

Activity II: The worksheet for this activity is found in the supplemental materials and is titled "Assessing Simpson's Diversity Index of a Plant Community."

Lab Preparation: Make sure that students install the Seek by iNaturalist app on their devices before coming to lab or at the beginning of lab. It can be found in both the Apple and Android app stores. Seek is the "student friendly" version of iNaturalist (it does not share location or other user data with other users) and is very user-friendly. However, if you prefer iNaturalist, it will also work with this activity. If you are unfamiliar with using Seek you should spend some time trying it out so you can help your students use it. The Seek downloadable user guide can be found on the app's website (https://www.inaturalist.org/pages/seek_app). You may choose to use the same area you used for Activity I, or a new area of campus. Again, look for areas with herbaceous growth that students can reach rather than forested areas with little undergrowth. Decide what transect lengths you want your students to use for the procedure. Use whatever lengths of tape makes sense for the given area and community. The lengths provided here (25m and 5m) are what work well for the author but are flexible based on area size, density of plants, and amount of time your class has to work outside. Modify the procedure and worksheet accordingly.

During the lab: Give a quick tutorial on using Seek before students establish their transects. Remind them that the app is not perfect and may sometimes misidentify plants. Encourage them to use their own observations and intuition to help identify plants as they become familiar with common ones. If there is a plant that Seek cannot identify down to the level of genus, tell students to give it a name that describes what it looks like and continue to use this name if they find more of it along their transect. Remind students to avoid Poison Ivy or other toxic-to-touch plants. Make sure students are completing the data tables correctly and ensure they are identifying plants to at least genus level. A common error students make when completing Table 3 in the "Results" of the worksheet is to enter Species Richness in the box labeled "N" rather than the total of all individual plants. The worksheet instructs them that N is the sum of all n, but double check to make sure students understand this. For Results and Conclusions, you can choose whether you want your students to graph data by hand or using Excel.

Potential extensions for Activity II: Like Activity I, you can compare data from this activity among different areas of campus or across years or seasons. If invasive species is a concept you cover in class, you may choose to have students determine whether species are native or non-native (this information is available on Seek) and then determine percentage of native vs. non-native plants in the area. If class projects are a part of grading criteria, consider having students choose a plant species from the sampling area to learn about more thoroughly, photograph, and/or sketch to contribute to a Campus Plant Guide that can be shared virtually with other members of the campus community.

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About the Author

Kimberly (Kimmy) Kellett is an Associate Professor of Biology at Perimeter College at Georgia State University. She instructs Biology and Environmental Science courses (lectures as well as labs) and is passionate about helping students experience and embrace nature. Kimmy obtained her PhD in Ecology and Certificate in College Teaching from the University of Georgia in 2015.

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