Quantifying Plant Biodiversity

Part 1: Background

It is common to hear ecologists talking about ***biodiversity***, particularly in terms of conservation biology. It is one of those terms that is used a lot, and is considered to refer to something important, yet, rarely is it clear exactly what is being discussed. In fact, 'biodiversity' can refer to many things, and has many specific definitions.

The most common definition of biodiversity refers to the number of different species in a given area or ***species diversity***. The greatest biodiversity by this measure would be the number of different species found in tropical rain forests (Fig. 1) which is estimated to be in the millions. Sometimes biologists refer to the diversity within a particular ***taxon***. For example, the southern Appalachians are the world's 'hotspot' for salamander diversity. There are many indices of species diversity that we will explore later.

Biodiversity, in the broad sense, can also refer to variation within species, or among populations. Many species have populations which can be differentiated by morphology or behavior. Typically this occurs within species with large ***ranges***. Consider for example, the extraordinary differences among human populations across the globe. This variation reflects underlying differences in allele proportions among populations and is called ***genetic diversity***. Genetic diversity is of special concern to endangered species because small populations tend to lose genetic diversity through random genetic drift. Without genetic diversity, populations lose their ability to adapt to changing environments, and are more susceptible to be decimated by disease. In populations with normal genetic diversity there will a range of disease resistance among individuals. An extreme example of a species with low genetic diversity is the cheetah (Fig. 2). Cheetah's are so similar genetically that they can accept skin grafts from unrelated individuals without tissue rejection.

On a larger scale, we can consider ***ecosystem diversity*** (Fig. 3). In this case we are not considering individual species, rather a species assemblage in a particular habitat. Ecosystem diversity is a broad concept, encompassing any level of ecological organization above species (e.g. ***habitat***, ***community***, and ***ecosystem***). An example of a major threat to ecosystem diversity in the US is the loss of wetlands to development. It is not easy to quantify ecosystem diversity, as the edges of things like habitat and communities are hard to define. However, it can be argued that the most natural way to preserve all levels of biodiversity is to protect as much and as varied habitat as possible, and then let nature take care of the rest.

Part 2: Measures of biodiversity

Abundance- This is not actually a measure of biodiversity *per se*, rather it is a count (or estimate) of all individuals present. Usually abundance refers to a certain species, but it can refer to all the individuals of all species present.

Species richness- This is the simplest measure of biodiversity being the tally of all the species in the area or community in question. While potentially easy to calculate, this measure is limited in that it lacks information of the relative abundance of the various species.

Community Dominance Index **(CDI)-** This index reflects how large a proportion of the total species present (in terms of numbers of individuals) is made up of the two most abundant species. It is calculated by the formula:

$$100\frac{y_1 + y_2}{y}$$

Where y_1 and y_2 are the abundances of the two most common species in the sample and y is the total abundance the sample.

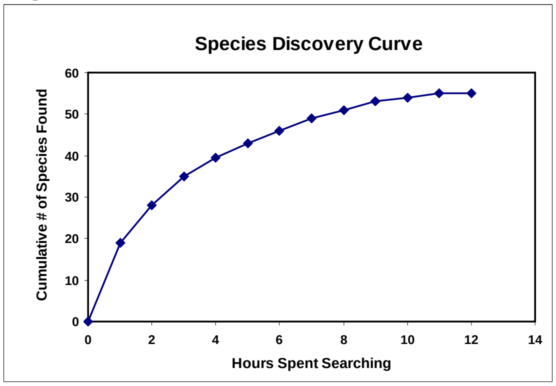
***Shannon-Weiner Index* (SWI)-** This index measures how evenly distributed the numbers of the species present in a sample are. Unlike the CDI, this calculates the value from all the species present, not just the top two. It is calculated by the formula:

$$H' = -\sum_{i=1}^{S} p_i \ln p_i$$

Where p_i is the proportional abundance of the *i*th species (abundance of i / total abundance) and S is the species richness. The higher the index, the more evenly distributed the sample is. The index is maximized if the species are all in equal proportions.

Species Discovery Curve- When sampling for biodiversity, how do you know when you have found all the species? Well, in short, you don't. However, you can get an idea of how many more you *could* find by plotting the cumulative number of species found against some standardized measure of sampling effort (Fig 4).

Fig 1.



The function will be a curve approaching an asymptote of the actual number of species present. The reason it is curved is not (necessarily) because the biologists are getting tired of searching. Rather, it reflects the fact that, as species found accumulate, there is a diminishing probability that the next individual found will be a new species. The curve is also a function of that fact that the most common species are found first, and the rare species are more likely to be missed. From the species discovery curve you can estimate how much more effort it will take to find new species. It allows you to know when you have found most of the species…and decide when it is time to give up.

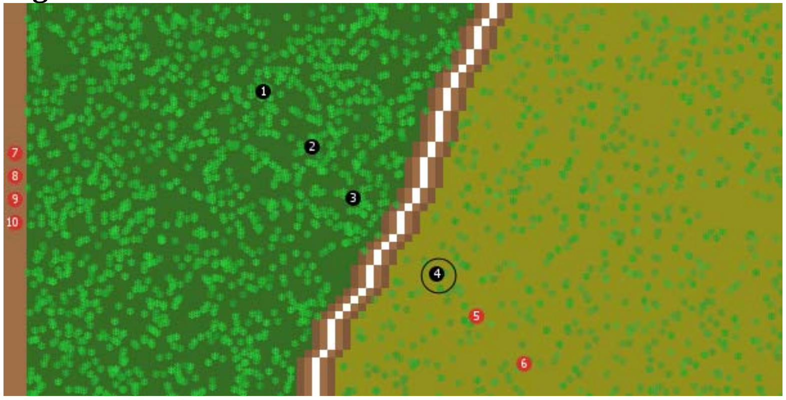
Jaccard Similarity Index- This measure is used to compare the species assemblages of two areas or habitats. It is used to define how similar two samples are in terms of species present. An example of when it would be useful is in deciding which watersheds to focus on protecting those which will preserve the most biodiversity. If you could only protect two of several, you would choose those with the lowest similarity index. The index is calculated as the number of species two samples have in common, divided by the total number of species represented in both samples.

$$J(A,B) = \frac{A \cap B}{A \cup B}$$

General note on sampling- You might imagine that it would take a long time to identify all the individuals in a sample to species, and it certainly would. Most communities have thousands of different species present, many of which appear quite similar. Fortunately, the biodiversity estimates work as long as you can separate individuals into recognizable groups. For example, you do not need to know what two species of snails actually are, you just need to correctly identify them as one or the other. However, the differences between species can be very subtle, and the better the categorizing, the better the estimates.

Part 3: Using the Model

Fig. 2



Now that we are familiar with the various diversity indices, we will explore the relationship of sampling effort to confidence in each index. In other words, how much effort will it really take to draw robust conclusions about the biodiversity of an area? For this we will need to generate data…lots of data. We will use a simulation model to calculate diversity indices of plants and compare two populations on opposite sides of a mountain range (Fig. 1). The west side of the mountain range is ***mesic habitat***, while the east side is ***xeric habitat***. From the Virtual Ecology website under Biodiversity models, click on 'Estimating Plant Diversity'. You will quickly see that this model will be data rich. You will move up to ten points around the habitats using the mouse. Then each point will be sampled generating local and cumulative data for 25 possible plant species. Sampled points will turn from red to black, and the current sample being reported will be encircled with a ring that roughly corresponds to the sample area. The controls and reporters are described in the tables below.

Table 3: Controls for Estimating Plant Diversity simulation

Control	Action
Reset All	Clears all reporters, resets/returns sample points, recreates the population
Move Pts	Enables the user to move sample points around the habitat
Reset Pts	Enables points to be re-sampled
Replicate	Enables re-sampling, recreates the population, clears all reporters
Sample_Radius	Adjusts the size of the area that will be sampled around each point
Sample (1-10)	Counts the numbers of each species around the identified point

Table 4: Reporters for Estimating Plant Diversity simulation

Reporter	Description
Current Sample (Sp1-Sp25)	Counts for each species in the highlighted sample
Cumulative Sample (Sp1-Sp25)	Counts for each species in the total sampled area
Current (3 stacked reporters)	Species richness, total abundance, and sampled area for the current sample
Cumulative (3 stacked reporters)	Species richness, total abundance, and sampled area for the cumulative sample

This simulation is different in that nothing moves except the sampling points (which are moved by right-click/holding the mouse). Also, there is no time recorded in the model. Where the stream sampling model compared species discovered to sampling time, this model compares species discovered to sampled area. The basic procedure is to lay out the sample points in a way that will best answer your question. For example, if you are interested in thoroughly quantifying the diversity west of the mountains, you would place all your points there. However, if you are comparing the habitats, or interested in the diversity across the entire area, you might divide them evenly between the two habitats (but remember, you can reset and reuse the points too). To conduct these virtual experiments you should have a spreadsheet open in which to record the data. You should also plan ahead how what data to collect, and how to organize it. Experimental design is one of the learning objectives for this lab. DON'T FORGET REPLICATION!

Sample Questions

1. *What is the relationship of sampled area to the* <u>*species richness*</u> *estimate? Is it better to collect a few large samples, or an equal total area of smaller ones? How would distribution of the species (clumped, random, or uniform) affect this?*

2. *Consider the questions above except for* <u>*species evenness*</u>*.*

3. *Compare the two habitats, considering species present and overall density. Which species are common to both and unique to each?*

4. *The difference in the two habitats is due to annual rainfall, with the mountain range creating a* ***rainshadow****. Why does this occur, and from which direction is the prevailing wind in this model? (Obviously, you will have to do some outside research on this one).*