

Biodiversity Laboratory

Calculating Biodiversity: Species Richness, Species Diversity, and How To Know When to Stop Sampling

Species Richness

Species richness is a measure of the number of species found in a sample. Since the larger the sample, the more species we would expect to find, the number of species is divided by the square root of the number of individuals in the sample. This particular measure of species richness is known as D, the Menhinick's index.

$$D = \frac{s}{\sqrt{N}}$$

where s equals the number of different species represented in your sample, and N equals the total number of individual organisms in your sample.

Species Diversity

Species diversity differs from species richness in that it takes into account both the numbers of species present and the dominance or evenness of species in relation to one another. As a measure of species diversity, we will calculate the Shannon index, H. Interestingly Shannon, a physicist, developed the index as a formula for measuring the entropy of matter in the universe. It turns out that the mathematical relationships hold true whether one is dealing with molecules in solution or species in an ecological community.

$$H = - \sum (p_i) \ln p_i$$

Where (p_i) is the proportion of the total number of individuals in the population that are in species "i".

Understanding the Difference Between Species Richness and Species Diversity

Consider the following data from samples of organisms obtained from two different biological communities, A and B.

Community A	
<u>Species # of individuals</u>	
A	59
B	12
C	11
D	10
E	5
F	3
Total	100

Community B	
<u>Species # of individuals</u>	
A	21
B	20
C	19
D	14
E	13
F	13
Total	100

Note that in both samples the same total number of individuals were obtained, and the same six species were found. The only difference seen between the two communities is in the distribution of the number of individuals among the six species.

If we calculate species richness for the two communities, $D = \frac{s}{\sqrt{N}}$

where s equals the number of different species represented in your sample, and N equals the total number of individual organisms in the sample, we find that the resulting numbers are the same, 0.6, because both samples have the same number of species for the same number of total individuals. In other words, the richness of species in the two communities is identical.

Now consider the species diversity of these two communities. In community A one species, Species A, numerically dominates the other five species. In community B the six species are more evenly represented. Because of this difference, community B would be considered to be more ‘diverse’ than community A despite both communities having the same total number of individuals and the same number of species. Thus, when measuring species diversity the relative abundance of each species must be taken into account.

In Table 1, species diversity is calculated for the two communities using the formula

$$H = \sum (p_i) |\ln p_i|$$

Where (p_i) is the relative abundance of species “i” in the community.

Table 1: Calculation of species diversity using the Shannon index, H

Community A				
Species	# of individ.	(p_i)	$ \ln p_i $	(p_i) $ \ln p_i $
A	59	.59	0.528	.311
B	12	.12	2.120	.254
C	11	.11	2.207	.243
D	10	.10	2.303	.230
E	5	.05	2.996	.150
F	3	.03	3.507	.105
Total	100	1.00		1.293

Community B				
Species	# of individ.	(p_i)	$ \ln p_i $	(p_i) $ \ln p_i $
A	21	.21	1.561	.328
B	20	.20	1.609	.322
C	19	.19	1.661	.316
D	14	.14	1.966	.275
E	13	.13	2.040	.265
F	13	.13	2.040	.265
Total	100	1.00		1.771

Question: What relative abundance would achieve the highest species diversity index?

In summary, the species diversity approach is generally a more reliable measure of biodiversity than species richness. While mathematically very easy to calculate, the limitations of the species richness concept can be seen when applying it to Communities A and B, where it fails to distinguish their quite different community structures.

How to Know When to Stop Sampling

A practical problem that arises when measuring species richness and species diversity is determining when you have done sufficient collecting to stop sampling, or in other words, to know when you've gotten just about all the species that matter. A good technique is to generate a cumulative species/sample (or cumulative species/area) curve, which plots the cumulative number of species collected (y-axis) vs. the number of samples collected (x-axis) as shown in Figure 1. This technique assumes that initially you will be collecting new species with each subsequent sample, but after a while you will be collecting the same species you have already collected in previous samples. Thus, you will get a curve that starts to flatten out. Once the curve levels off there is no need to sample further.

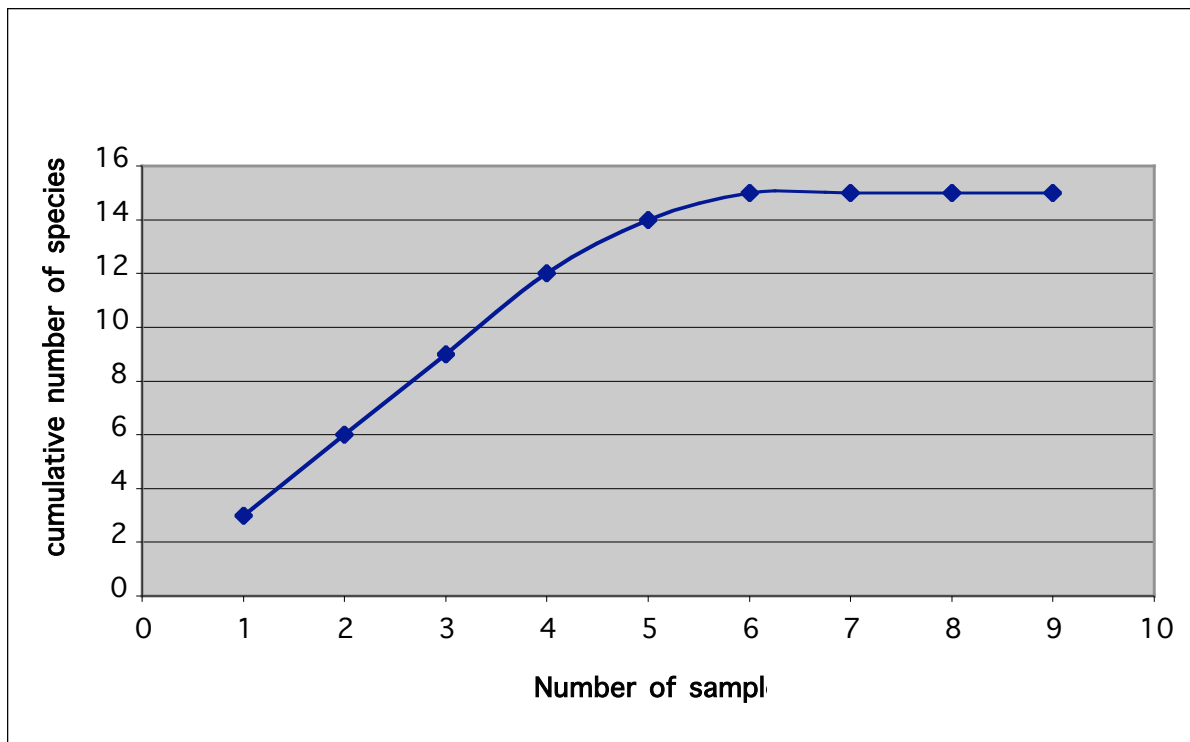


Figure 1: A species/sample curve generated by counting the number of new species accumulated as more and more samples are gathered from a sampling area.