

Measuring biodiversity of ecological communities

Biodiversity is one of the primary interests of ecologists, but quantifying the species diversity of ecological communities is complicated. In addition to issues of statistical sampling, the rather arbitrary nature of delineating an ecological community, and the difficulty of positively identifying all of the species present, species diversity itself has two separate components: 1.) the number of species present (*species richness*), and 2.) their relative abundances (termed *dominance* or *evenness*).

As a result, many different measures (or *indices*) of biodiversity have been developed, and whole books have been written explaining and comparing them (Magurran 2004). Here, we will explore two measures of biodiversity: The Shannon index (H' , also termed the Shannon-Wiener index) and the Simpson index (D). We will then consider one measure used to compare diversity among communities, Jaccard's similarity index.

Shannon index

The idea behind this index is that the diversity of a community is similar to the amount of *information* in a code or message. It is calculated in the following way:

$$H' = - \sum p_i \ln p_i$$

where p_i is the proportion of individuals found in species i . For a well-sampled community, we can estimate this proportion as $p_i = n_i/N$, where n_i is the number of individuals in species i and N is the total number of individuals in the community. Since by definition the p_i s will all be between zero and one, the natural log makes all of the terms of the summation negative, which is why we take the inverse of the sum.

Interpretation: Typical values are generally between 1.5 and 3.5 in most ecological studies, and the index is rarely greater than 4. The Shannon index increases as both the richness and the evenness of the community increase. The fact that the index incorporates both components of biodiversity can be seen as both a strength and a weakness. It is a strength because it provides a simple, synthetic summary, but it is a weakness because it makes it difficult to compare communities that differ greatly in richness.

Due to the confounding of richness and evenness in the Shannon index, many biodiversity researchers prefer to stick to two numbers for comparative studies,

combining a direct estimate of species richness (the total number of species in the community, S) with some measure of dominance or evenness. The most common dominance measure is Simpson's index.

Simpson's index

Since evenness and dominance are simply two sides of the same coin, their measures are complimentary. Simpson's index is based on the probability of any two individuals drawn at random from an infinitely large community belonging to the same species:

$$D = \sum p_i^2$$

where again p_i is the proportion of individuals found in species i . For a finite community, this is

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

Interpretation: Now D is a measure of dominance, so as D increases, diversity (in the sense of evenness) decreases. Thus, Simpson's index is usually reported as its complement $1-D$ (or sometimes $1/D$ or $-\ln D$). Since D takes on values between zero and one and approaches one in the limit of a monoculture, $(1-D)$ provides an intuitive proportional measure of diversity that is much less sensitive to species richness.

Comparing communities: Jaccard's index

Of course, we are usually interested not just in the diversity of a single site, but in comparing biodiversity levels across sites. An intuitive measure of similarity between two samples can summarize the fraction of species they share. Jaccard's index is the simplest summary of this, taking the following form:

$$J = \frac{s_c}{s_a + s_b + s_c}$$

where s_a and s_b are the numbers of species unique to samples a and b , respectively, and s_c is the number of species common to the two samples.

Interpretation: Jaccard's index of similarity is very straightforward since it is simply the fraction of species shared between the samples. Keep in mind, however, that Jaccard's index only utilizes the richness component of diversity,

since it does not entail any information on abundance. As a pairwise measure, we can examine how Jaccard's index varies with the distance or environmental differences between the sites.

YOUR ASSIGNMENT

1. Having surveyed your tabletop forest, calculate:
 - a. the species richness (S),
 - b. Shannon diversity (H') and
 - c. Simpson's diversity ($1-D$) for your sample.
2. In consultation with each of the other groups
 - a. Compare your samples, based on the different measures of diversity. Rank the four samples. Do the different measures of diversity all agree? Explain
 - b. Calculate Jaccard's similarity for each pair of sites. How do they compare?

REFERENCES

Magurran, A.E. 2004. *Measuring Biological Diversity*. Blackwell.