10.1: Introduction, Simpson's Index and Shannon-Weiner Index

As forest and natural resource managers, we must be aware of how our timber management practices impact the biological communities in which they occur. A silvicultural prescription is going to influence not only the timber we are growing but also the plant and wildlife communities that inhabit these stands. Landowners, both public an(18)}{d private, often require management of non-timber components, such as wildlife, along with meeting the financial objectives achieved through timber management. Resource managers must be cognizant of the effect management practices have on plant and wildlife communities. The primary interface between timber and wildlife is habitat, and habitat is simply an amalgam of environmental factors necessary for species survival (e.g., food or cover). The key component to habitat for most wildlife is vegetation, which provides food and structural cover. Creating prescriptions that combine timber and wildlife management objectives are crucial for sustainable, long-term balance in the system.

So how do we develop a plan that will encompass multiple land use objectives? Knowledge is the key. We need information on the habitat required by the wildlife species of interest and we need to be aware of how timber harvesting and subsequent regeneration will affect the vegetative characteristics of the system. In other words, we need to understand the diversity of organisms present in the community and appreciate the impact our management practices will have on this system.

Diversity of organisms and the measurement of diversity have long interested ecologists and natural resource managers. Diversity is variety and at its simplest level it involves counting or listing species. Biological communities vary in the number of species they contain (richness) and relative abundance of these species (evenness). Species richness, as a measure on its own, does not take into account the number of individuals of each species present. It gives equal weight to those species with few individuals as it does to a species with many individuals. Thus a single yellow birch has as much influence on the richness of an area as 100 sugar maple trees. Evenness is a measure of the relative abundance of the different species making up the richness of an area. Consider the following example.

Example 10.1.1:

Number of Individuals

Tree Species	Sample 1	Sample 2
Sugar Maple	167	391
Beech	145	24
Yellow Birch	134	31

Both samples have the same richness (3 species) and the same number of individuals (446). However, the first sample has more evenness than the second. The number of individuals is more evenly distributed between the three species. In the second sample, most of the individuals are sugar maples with fewer beech and yellow birch trees. In this example, the first sample would be considered more diverse.

A diversity index is a quantitative measure that reflects the number of different species and how evenly the individuals are distributed among those species. Typically, the value of a diversity index increases when the number of types increases and the evenness increases. For example, communities with a large number of species that are evenly distributed are the most diverse and communities with few species that are dominated by one species are the least diverse. We are going to examine several common measures of species diversity.

Simpson's Index

Simpson (1949) developed an index of diversity that is computed as:

$$D=\sum_{i=1}^{R}\left(\frac{n_i(n_i-1)}{N(N-1)}\right) \tag{10.1.1}$$

where *ni* is the number of individuals in species *i*, and *N* is the total number of species in the sample. An equivalent formula is:

$$D = \sum_{i=1}^{R} p_i^2 \tag{10.1.2}$$

where p_i is the proportional abundance for each species and *R* is the total number of species in the sample. Simpson's index is a weighted arithmetic mean of proportional abundance and measures the probability that two individuals randomly selected from a sample will belong to the same species. Since the mean of the proportional abundance of the species increases with decreasing number of species and increasing abundance of the most abundant species, the value of *D* obtains small values in data sets of high diversity and large values in data sets with low diversity. The value of Simpson's D ranges from 0 to 1, with 0 representing infinite diversity and 1 representing no diversity, so the larger the value of D, the lower the diversity. For this reason, Simpson's index is usually expressed as its inverse (1/*D*) or its compliment (1-*D*) which is also known as the Gini-Simpson index. Let's look at an example.

Example 10.1.2:calculating Simpson's Index

We want to compute Simpson's D for this hypothetical community with three species.

Species	No. of individuals
Sugar Maple	35
Beech	19
Yellow Birch	11

First, calculate N.

$$N = 35 + 19 + 11 = 65$$

Then compute the index using the number of individuals for each species:

$$D = \sum_{i=1}^{R} \left(\frac{n_i(n_i - 1)}{N(N-1)}\right) = \left(\frac{35(34)}{65(64)} + \frac{19(18)}{65(64)} + \frac{11(10)}{65(64)}\right) = 0.3947$$

The inverse is found to be:

$$\frac{1}{0.3947} = 2.5336$$

Using the inverse, the value of this index starts with 1 as the lowest possible figure. The higher the value of this inverse index the greater the diversity. If we use the compliment to Simpson's D, the value is:

$$1 - 0.3947 = 0.6053$$

This version of the index has values ranging from 0 to 1, but now, the greater the value, the greater the diversity of your sample. This compliment represents the probability that two individuals randomly selected from a sample will belong to different species. It is very important to clearly state which version of Simpson's D you are using when comparing diversity.

Shannon-Weiner Index

The Shannon-Weiner index (Barnes et al. 1998) was developed from information theory and is based on measuring uncertainty. The degree of uncertainty of predicting the species of a random sample is related to the diversity of a community. If a community has low diversity (dominated by one species), the uncertainty of prediction is low; a randomly sampled species is most likely going to be the dominant species. However, if diversity is high, uncertainty is high. It is computed as:

$$H' = -\sum_{i=1}^{R} ln(p_i) = ln\left(\frac{1}{\prod_{i=1}^{R} p_i^{p_i}}\right) \tag{10.1.3}$$

where *pi* is the proportion of individuals that belong to species *i* and *R* is the number of species in the sample. Since the sum of the *pi*'s equals unity by definition, the denominator equals the weighted geometric mean of the *pi* values, with the *pi* values being used as weights. The term in the parenthesis equals true diversity *D* and H'=ln(*D*). When all species in the data set are equally common, all *p*i values = 1/*R* and the Shannon-Weiner index equals ln(*R*). The more unequal the abundance of species, the larger the weighted geometric mean of the *p*i values, the smaller the index. If abundance is primarily concentrated into one species, the index will be close to zero.

An equivalent and computationally easier formula is:

$$H' = \frac{N ln\, N - \sum (n_i ln\, n_i)}{N} \tag{10.1.4}$$

where *N* is the total number of species and *n*i is the number of individuals in species *i*. The Shannon-Weiner index is most sensitive to the number of species in a sample, so it is usually considered to be biased toward measuring species richness.

Let's compute the Shannon-Weiner diversity index for the same hypothetical community in the previous example.

Example 10.1.3:Calculating Shannon-Weiner Index

Species	No. of individuals
Sugar Maple	35
Beech	19
Yellow Birch	11

We know that N = 65. Now let's compute the index:

$$H' = \frac{271.335 - (124.437 + 55.944 + 26.377)}{65} = 0.993$$