Calculating Community Similarity and Diversity Indices

Biological systems are organized on many different levels: molecules, cells, organisms, populations, communities and ecosystems. **Species diversity** is a characteristic unique to the community level of biological organization. Higher species diversity is generally thought to indicate a more complex and healthier community because a greater variety of species allows for more species interactions, hence greater system stability, and indicates good environmental conditions. A variety of **diversity indices** can be calculated to compare ecological communities. In addition, pairs of communities can be compared using **community similarity** indices.

Species diversity has two parts.

a) **Richness** refers to the number of species found in a community and
b) **Evenness** refers to the relative abundance of each species.

A community is said to have high species diversity if many nearly equally abundant species are present. If a community has only a few species or if only a few species are very abundant, then species diversity is low.

Consider a community with 100 individuals distributed among 10 species. It should make sense that if there are 10 individuals in each of the 10 species in the community it is more diverse than if there are 91 individuals in one species and one individual in each of the other nine species.

Exercise 1: Calculating the Proportional Index of Community Similarity

A good way to compare communities in different places or at different times is to examine community similarity. You will use a simple measure, called **Proportional Similarity**, to compare fish communities in Northrup Creek. Table 1 gives an example of this method.

Table 1. The percent of fish sampled in each species in community 1 and community 2 (e.g., 50 = # of species 1 captured in community 1; 93 = total # of fish captured in community 1).

Species	Community 1	Community 2
1	50/93 = 54%	0/112 = 0%
2	25/93 = 27%	7/112 = 6%
3	12/93 = 13%	15/112 = 13%
4	6/93 = 6%	30/112 = 27%
5	0/93 = 0%	60/112 = 54%
Total	93 fish sampled	112 fish sampled

PS (Percent Similarity) = (lowest percent value of a species between communities), in this case:

PS = 0% + 6% + 13% + 6% + 0% = **25%** (Equation 1)

Exercise 2: Simpson's Index of Diversity

Simpson's Index calculates the probability that two organisms sampled from a community of will belong to different species (the more even the abundance of individuals across species, the higher the probability that the two individuals sampled will belong to different species). Simpson's Index values range from 0 to 1, with 1 representing perfect evenness (all species present in equal numbers). The formula for Simpson's Index is:

$$D_s = 1 - \text{Sum}_1^i\ [n_i*(n_i-1)]/[N*(N-1)] \quad \text{(Equation 2)}$$

where = add all $n_i*(n_i-1)$ values together, n_i = the number of individuals in the i^{th} species collected, and N = the total number of organisms in the sample. For example, suppose you collected 3 species with 40, 25 and 15 individuals, respectively.

$$\begin{aligned} D_s &= 1 - \frac{40(39) + 25(24) + 15(14)}{80(79)} \\ &= 1 - \frac{2370}{6320} \\ &= 1 - 0.375 \\ &= 0.625 \end{aligned}$$

Exercise 3: Determining Statistically Significant Differences in Simpson's Diversity

Inevitably, the D_s values you calculate for each community you sample will be different. How can you tell if the communities have significantly different D_s values or not? To answer this question requires using **statistics**, a branch of mathematics that allows you to determine with a known degree of reliability how likely it is that two or more groups are the same or not. To make this kind of comparison, you need to calculate the variability in the data you collected (the more variable the data, the greater the difference in the diversity values has to be to show a significant difference between any two D_s values). The formula to calculate the **variance** (**s^2**) of Simpson's Index is:

$$s^2 = 4[p_i^3 - (p_i^2)^2]/N \qquad \text{(Equation 3)}$$

where $\mathbf{p_i}$ is the proportion of the number of organisms in the i^{th} species ($\mathbf{n_i}$) to the total number of organisms in the sample (**N**). Therefore, $\mathbf{p_i = n_i/N}$ (these are the same values you used to calculate Simpson's Diversity). Using the data from the example from Equation 2, you can calculate **s^2**.

$$\begin{aligned} \mathbf{s^2} &= 4\{[(40/80)^3 + (25/80)^3 + (15/80)^3] - [(40/80)^2 + (25/80)^2 + (15/80)^2]^2\}/80 \\ &= 4\{[0.125 + 0.031 + 0.007] - [0.250 + 0.098 + 0.035]^2\}/80 \\ &= 4\{[0.163] - [0.383]^2\}/80 \\ &= 4(0.160)/80 \\ &= 0.0008 \end{aligned}$$

You will use a **t-test** to determine whether or not Simpson's diversity values are different for the fish communities above and below the WTP.

$$t = [\text{avg. } 1 - \text{avg. } 2]/[\text{sqrt}(s_1^2+s_2^2)] \qquad \text{(Equation 4)}$$

For example, suppose that diversities in two hypothetical communities are 0.8 and 0.3, respectively, and that the variances of the two diversity estimates are 0.03 (s^2_1) and 0.01 (s^2_2), respectively.

$$t = \frac{0.8 - 0.3}{\text{sqrt}(0.03+0.01)}$$
$$= 0.5/0.2$$
$$= 2.5$$

For this example, if the degrees of freedom (# taxa in community 1 + # taxa in community 2 - 2 = $n_1 + n_2 - 2$) are 8, the t-table value is 2.306 (see last page). For any calculated value of "t" greater than the number you find in the table, the difference in diversity between the two communities is considered to be significant. For any calculated value of "t" less than the number you find in the table, the difference in diversity between the two communities is not considered to be significant. For these calculations, statistical significance means there is 1 chance in 20 (5%) that the data show a difference in community diversity values when in reality there is no difference.

References

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Powell, F.C. 1982. Statistical Tables for the Social, Biological and Physical Sciences. Cambridge University Press. London.