Diversity Indices: Simpson’s D and E

# Introduction

A diversity index is a mathematical measure of species diversity in a community. Diversity indices provide more information about community composition than simply species richness (i.e., the number of species present); they also take the relative abundances of different species into account. Consider two communities of 100 individuals each and composed of 10 different species. One community has 10 individuals of each species; the other has one individual of each of nine species, and 91 individuals of the tenth species. Which community is more diverse? Clearly the first one is, but both communities have the same species richness. By taking relative abundances into account, a diversity index depends not only on species richness but also on the evenness, or equitability, with which individuals are distributed among the different species.

# Importance

Diversity indices provide important information about rarity and commonness of species in a community. The ability to quantify diversity in this way is an important tool for biologists trying to understand community structure.

# Questions

How do we measure diversity?

# Variables

|  |  |
| --- | --- |
| D | Simpson's diversity index |
| S | total number of species in the community (richness) |
| pi | proportion of *S* made up of the *i*th species |
| ED | equitability (evenness) |

# Methods

Simpson's diversity index (*D*) is a simple mathematical measure that characterizes species diversity in a community. The proportion of species *i* relative to the total number of species (*pi*) is calculated and squared. The squared proportions for all the species are summed, and the reciprocal is taken:

|  |  |
| --- | --- |
| $$D=\frac{1}{\sum\_{i=1}^{S}p\_{i}^{2}}$$ | LaTeX Code: \[ D = \frac{1}{\sum\_{i=1}^{S} p\_i^2} \] |

For a given richness (*S*), *D* increases as equitability increases, and for a given equitability *D* increases as richness increases. Equitability (*ED*) can be calculated by taking Simpson's index (*D*) and expressing it as a proportion of the maximum value *D* could assume if individuals in the community were completely evenly distributed (*D*max, which equals *S --* as in a case where there was one individual per species). Equitability takes a value between 0 and 1, with 1 being complete evenness.

|  |  |
| --- | --- |
| $$E\_{p}=\frac{D}{D\_{max}}=\frac{1}{\sum\_{i=1}^{S}p\_{i}^{2}}×\frac{1}{S}$$ | LaTeX Code: \[ E\_p = \frac{D}{D\_{max}} = \frac{1}{\sum\_{i=1}^{S} p\_i^2} \times \frac{1}{S} \] |

Siemann *et al*. (1997) collected the following data on oak savanna arthropod communities to investigate the effects of prescribed burning on arthropods. The abundance data below represent the number of individuals per family (rather than per species) collected in sweep-net sampling during a two year period (1992-1993) (from Siemann *et al*. 1997).

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Order | Family | 1992 | *pi* | 1993 | *pi* |
| Araneida | Araneidae | 114 | 0.013 | 33 | 0.024 |
|  | Misc (5 families) | 66 | 0.008 | 0 | 0.000 |
| Coleoptera | Carabidae | 0 | 0.000 | 1 | 0.001 |
|  | Chrysomelidae | 128 | 0.015 | 58 | 0.042 |
|  | Helodidae | 164 | 0.019 | 5 | 0.004 |
|  | Scarabaeidae | 1 | 0.000 | 2 | 0.001 |
|  | Staphylinidae | 5 | 0.001 | 2 | 0.001 |
|  | Misc (23 families) | 477 | 0.056 | 56 | 0.041 |
| Diptera | Anthomyiidae | 262 | 0.031 | 172 | 0.125 |
|  | Chamaemyidae | 27 | 0.003 | 29 | 0.021 |
|  | Chironomidae | 0 | 0.000 | 0 | 0.000 |
|  | Chloropidae | 87 | 0.010 | 1 | 0.001 |
|  | Culicidae | 0 | 0.000 | 6 | 0.004 |
|  | Dolichopodidae | 315 | 0.037 | 117 | 0.085 |
|  | Platystomatidae | 345 | 0.040 | 137 | 0.099 |
|  | Syrphidae | 100 | 0.012 | 29 | 0.021 |
|  | Tephritidae | 191 | 0.022 | 3 | 0.002 |
|  | Misc (26 families) | 438 | 0.051 | 111 | 0.080 |
| Hemiptera | Miridae | 2177 | 0.254 | 55 | 0.040 |
|  | Misc (10 families) | 150 | 0.018 | 29 | 0.021 |
| Homoptera | Aphididae | 0 | 0.000 | 0 | 0.000 |
|  | Cicadellidae | 1465 | 0.171 | 86 | 0.062 |
|  | Delphacidae | 272 | 0.032 | 21 | 0.015 |
|  | Membracidae | 265 | 0.031 | 23 | 0.017 |
|  | Misc (6 families) | 132 | 0.015 | 4 | 0.003 |
| Hymenoptera | Formicidae | 0 | 0.000 | 0 | 0.000 |
|  | Misc (28 families) | 316 | 0.037 | 24 | 0.017 |
| Lepidoptera | Noctuidae | 72 | 0.008 | 5 | 0.004 |
|  | Pyralidae | 13 | 0.002 | 20 | 0.015 |
|  | Tortricidae | 8 | 0.001 | 0 | 0.000 |
|  | Misc (4 families) | 73 | 0.009 | 0 | 0.000 |
| Odonata | Coenagrionidae | 0 | 0.000 | 202 | 0.146 |
|  | Misc (2 families) | 0 | 0.000 | 2 | 0.001 |
| Orthoptera | Acrididae | 564 | 0.066 | 138 | 0.100 |
|  | Gryllidae | 4 | 0.000 | 0 | 0.000 |
|  | Tettigoniidae | 264 | 0.031 | 0 | 0.000 |
|  | Misc (3 families) | 3 | 0.000 | 0 | 0.000 |
| Trichoptera | Leptoceridae | 0 | 0.000 | 0 | 0.000 |
|  | Phryganeidae | 0 | 0.000 | 0 | 0.000 |
| Miscellaneous | (3 orders, 4 families) | 63 | 0.007 | 8 | 0.006 |

Although we do not have species data, we can calculate family diversity and equitability using these data. The proportions (*pi* values) have been calculated by dividing the number of individuals in a given family by the total number of individuals collected in a year (8,561 in 1992 and 1,379 in 1993). To calculate Simpson's *D*, we square each proportion (*pi*), sum these squared values, and take the reciprocal (divide one by the sum). For example, for the 1992 data, Simpson's *D* is calculated (1 / [0.0132 + 0.0082 + 0.0002 + 0.0152 + ... + 0.0072]) = 8.732. We could then calculate the equitability (*ED*) quite easily using the second equation above (*ED* = *D* / *D*max, with *D*max = *S*). Here, we will use the number of families in place of *S*, so that E = 8.732 / 31 = 0.2817.

# Interpretation

What we have calculated is an index of family diversity and evenness, rather than the standard index of species diversity and evenness. Based on the value of 0.2817 calculated for *ED*, we could describe the equitability, or evenness of individuals' distributions among families, in this community as relatively low (recall that *ED* assumes a value between 0 and 1, and 1 is complete equitability).

# Conclusion

Simpson's *D* is one of many diversity indices used by biologists. Others include the [Shannon index (*H*)](http://www.tiem.utk.edu/~gross/bioed/bealsmodules/shannonDI.html), the Berger-Parker index (*d*), Hill's *N*1, and Q-statistics. Each of these indices has strengths and weaknesses. An ideal index would discriminate clearly and accurately between samples, not be greatly affected by differences in sample size, and be relatively simple to calculate. Biologists often use a combination of several indices to take advantages of the strengths of each and develop a more complete understanding of community structure.

# Additional Questions

1. Calculate *D* and *ED* for the 1993 samples. How do these values compare to the ones calculated for the 1992 samples?

2. The following graph shows two different diversity indices (Simpson's *D* and [Shannon's *H*](http://www.tiem.utk.edu/~gross/bioed/bealsmodules/shannonDI.html) and their associated evenness indices (*ED* and *EH*) calculated for four communities composed of 5, 10, 20 and 50 species, respectively. In each community, 90% of the individuals belong to one species, and the other 10% of the individuals are evenly divided among the remaining species. How do the indices differ across communities? (The diversity indices, and therefore the evenness indices, cannot be compared directly to one another, but we can compare how they change for the different communities). Would your conclusions about these communities be different depending on which diversity index you used?



# Source

Begon, M., J. L. Harper, and C. R. Townsend. 1996. *Ecology: Individuals, Populations, and Communities, 3rd edition.* Blackwell Science Ltd., Cambridge, MA.

Magurran, A. E. 1988. *Ecological Diversity and its Measurement*. Princeton University Press, Princeton, NJ.

Rosenzweig, M. L. 1995. *Species Diversity in Space and Time*. Cambridge University Press, New York, NY.

Siemann, E., J. Haarstad, and D. Tilman. 1997. Short-term and long-term effects of burning on oak savanna arthropods. *American Midland Naturalist 137*:349-361.

# About this Resource

This material was originally distributed as part of “Alternative Routes to Quantitative Literacy for the Life Sciences[[1]](#endnote-1)” - National Science Foundation Award DUE-9752339 to the University of Tennessee, Knoxville for August 1, 1998 - July 31, 2000. Principal Investigator: Louis J. Gross. Co-Principal Investigators: Beth C. Mullin and Susan E. Riechert.

This material is now being revised as part of the “Resources for Improving Quantitative Skills in Community College Biology[[2]](#endnote-2)” project. As part of that project is also aligned with the OpenStax Biology Textbook[[3]](#endnote-3).

It is published using the QUBES Open Education Resources publishing platform[[4]](#endnote-4).

1. http://www.tiem.utk.edu/~gross/bioed/ [↑](#endnote-ref-1)
2. https://qubeshub.org/community/groups/quantbioatcc/ [↑](#endnote-ref-2)
3. https://openstax.org/details/books/biology-2e [↑](#endnote-ref-3)
4. https://qubeshub.org/qubesresources/publications/1058/ [↑](#endnote-ref-4)