Diversity Indices: Shannon’s H 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 (for an illustration of this point, see below, or introduction to [SIMPSON'S *D* AND *E*](http://www.tiem.utk.edu/~gross/bioed/bealsmodules/simpsonDI.html)).

# 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

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

# Methods

The Shannon diversity index (*H*) is another index that is commonly used to characterize species diversity in a community. Like [Simpson's](http://www.tiem.utk.edu/~gross/bioed/bealsmodules/simpsonDI.html) index, Shannon's index accounts for both abundance and evenness of the species present. The proportion of species *I* relative to the total number of species (*pi*) is calculated, and then multiplied by the natural logarithm of this proportion (ln*pi*). The resulting product is summed across species, and multiplied by -1:

|  |  |
| --- | --- |
|  | LaTeX Code: \[ H = - \sum\_{i=1}^{S} p\_i \ln p\_i \] |

Shannon's equitability (*EH*) can be calculated by dividing *H* by *H*max (here *H*max = ln*S*). Equitability assumes a value between 0 and 1 with 1 being complete evenness.

|  |  |
| --- | --- |
|  | LaTeX Code: \[ E\_H = H / H\_{max} = H / \ln{S} \] |

*Example:*

The graph below shows *H* and *EH* for four hypothetical communities, each consisting of 100 individuals. The communities are composed of 5, 10, 20 and 50 species, respectively. For each community *H* and *EH* have been calculated for the case in which individuals are distributed evenly among the different species (i.e., each species makes up an equal proportion of *S*), and for the case in which one species has 90% of the individuals, and the remaining individuals are distributed evenly. For example, in a community with 10 species in which the species contain equal numbers of individuals, *p* = 0.1 for each species. In a community with 10 species in which one species has 90% of the individuals, *p* = 0.9 for the dominant species, and *p* = 0.01 for the other nine species. The diamonds represent *H* and *EH* values for the first case (equal proportions), and the triangles represent values for *H* and *EH* for the second case (unequal proportions).



For the first case, *EH* is always equal to one (complete evenness, or equitability), but *H* increases dramatically as the number of species increases, as we would expect. For the second case, in which one species makes up 90% of the community, the picture is a little different. Here we can see that although *H* does increase with increasing numbers of species, it does so much more slowly than in the first case. Additionally, *EH* decreases as species number increases (since one species always makes up 90% of the community in the second case of this hypothetical example, the remaining species make up some fraction of 10% of the community; as species number increases this fraction becomes smaller and evenness decreases). *H* and *EH* clearly give more information about these communities than would species number (richness) alone.

The following table contains data from a study of Costa Rican ant diversity (Roth *et al*. 1994). The authors measured diversity in four different habitats ranging very low levels of human disturbance (primary rain forest) to very high levels of human disturbance (banana plantations) to assess the impacts of different levels of disturbance on biological diversity. For each habitat studied we will use data collected from one site within that habitat. The numbers below represent relative proportions of each species (from Roth *et al*. 1994 [family names have been omitted]).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Formicidae | Primary Forest | Abandoned cacao plantations | Productive cacao plantations | Banana plantations |
| *Acromyrmex sp. 1* |  |  | 0.013 |  |
| *A. volcanus* |  |  | 0.006 |  |
| *A. araneoides* | 0.117 | 0.140 |  |  |
| *Atta cephalotes* |  | 0.010 |  |  |
| *Carabarella sp. 1* | 0.004 |  |  |  |
| *Cardiocondylasp. 1* |  |  |  | 0.011 |
| *Crematogastersp. 2* | 0.021 | 0.024 |  |  |
| *Cyphomyrmexsp. 1* |  |  |  | 0.011 |
| *Erebomyrma nevermanni* | 0.004 | 0.021 |  |  |
| *Pheidole sp. 1* | 0.021 | 0.035 | 0.019 |  |
| *Pheidole sp. 2* | 0.008 | 0.045 | 0.013 |  |
| *Pheidole sp. 3* | 0.058 | 0.021 |  |  |
| *Pheidole sp. 5* | 0.054 | 0.010 |  |  |
| *Pheidole sp. 7* |  |  | 0.006 |  |
| *Pheidole sp. 9* | 0.021 |  |  |  |
| *Pheidole sp. 10* | 0.004 |  |  |  |
| *Pheidole sp. 11* |  | 0.024 |  |  |
| *Pheidole sp. 12* | 0.004 | 0.003 |  |  |
| *Pheidole sp. 15* | 0.163 |  |  |  |
| *Pheidole sp. 16* |  | 0.003 |  |  |
| *Pheidole sp. 19* | 0.004 | 0.017 |  |  |
| *Pheidole sp. 22* | 0.067 |  |  |  |
| *Pheidole sp. 23* | 0.004 |  |  |  |
| *Pheidole sp. 24* | 0.017 |  |  | 0.011 |
| *Pheidole sp. 25* |  | 0.157 |  |  |
| *Pheidole sp. 26* |  |  |  | 0.005 |
| *Pheidole sp. 27* |  | 0.003 |  |  |
| *Pheidole sp. 28* |  | 0.003 |  |  |
| *Pheidole sp. 31* |  | 0.010 |  |  |
| *Pheidole sp. 34* |  |  |  | 0.005 |
| *Pheidole sp. 36* | 0.125 | 0.007 |  |  |
| *P. annectans* | 0.079 | 0.028 |  | 0.005 |
| *P. longiscapa* | 0.050 | 0.003 |  |  |
| *P. punctatissima* |  |  |  | 0.005 |
| *P. nr. subarmata* |  | 0.003 |  |  |
| *P. subarmata* |  |  |  | 0.043 |
| *P. fiorii* | 0.075 |  |  |  |
| *Sericomyrmexsp. 1* |  |  | 0.006 |  |
| *Solenopsis sp. 1* | 0.004 |  | 0.006 |  |
| *Solenopsis sp. 3* | 0.004 | 0.077 |  |  |
| *Solenopsis sp. 4* | 0.017 |  |  |  |
| *Solenopsis sp. 5* | 0.004 |  |  |  |
| *Solenopsis sp. 6* | 0.004 |  |  |  |
| *Solenopsis sp. 7* |  | 0.038 |  |  |
| *Solenopsis sp. 8* |  | 0.042 |  |  |
| *Solenopsis sp. 9* |  | 0.035 |  |  |
| *S. geminata* |  | 0.031 | 0.101 | 0.830 |
| *Tetramorium bicarinatum* |  |  |  | 0.005 |
| *Trachymyrmexsp. 1* |  | 0.003 | 0.019 |  |
| *Trachymyrmexsp. 2* |  |  |  |  |
| *Trachymyrmexsp. 3* | 0.004 | 0.007 |  |  |
| *Wasmannia sp. 1* |  |  |  | 0.011 |
| *W. auropunctata* | 0.050 | 0.021 | 0.006 |  |
| *Pseudomyrmexsp. 1* |  |  |  |  |
| *Ectatomma gibbum* | 0.004 |  |  |  |
| *E. ruidum* | 0.004 | 0.038 | 0.753 |  |
| *E. tuberculatum* |  |  |  |  |
| *Gnamptogenyssp. 2* |  |  |  |  |
| *Gnamptogenyssp. 3* |  |  |  |  |
| *Gnamptogenyssp. 4* |  |  |  |  |
| *G. bispinosa* |  |  |  |  |
| *Hypoponera sp. 1* | 0.004 | 0.010 |  |  |
| *Hypoponera sp. 2* |  | 0.007 |  |  |
| *Hypoponera sp. 3* |  |  |  | 0.005 |
| *Hypoponera sp. 4* |  |  |  | 0.011 |
| *Odontomachus bauri* |  |  |  |  |
| *O. brunneus* | 0.004 |  |  |  |
| *O. chelifer* | 0.021 |  |  |  |
| *O. erythrocephalus* | 0.017 |  | 0.006 | 0.043 |
| *O. hastatus* |  |  |  |  |
| *O. laticeps* | 0.008 | 0.010 |  |  |
| *O. opaciventris* |  |  |  |  |
| *Pachycondyla apicalis* | 0.017 | 0.007 |  |  |
| *P. constricta* |  |  | 0.006 |  |
| *P. harpax* | 0.0125 | 0.031 | 0.013 |  |
| *P. obscuricornis* |  | 0.003 | 0.006 |  |
| *P. villosa* |  |  |  |  |
| *Paraponera clavata* |  |  | 0.019 |  |
| *Brachymyrmexsp. 1* |  |  |  |  |
| *Brachymyrmexsp. 2* |  |  |  |  |
| *Campanotus sp. 1* |  |  |  |  |
| *Paratrechina sp. 1* | 0.033 | 0.063 |  |  |
| *Paratrechina sp. 2* |  |  |  |  |
| *Tapinoma melanocephalum* |  |  |  |  |
| total # of species per site: | 37 | 36 | 16 | 14 |

To calculate Shannon's H for the primary forest site we can use the equation given above: H = (-1) \* (0.117 \* ln 0.117) + (0.004 \* ln 0.004) + (0.021 \* ln 0.021) + (0.004 \* ln 0.004) + (0.021 \* ln 0.021) + (0.008 \* ln 0.008) + (0.058 \* ln 0.058) + (0.054 \* ln 0.054) + (0.021 \* ln 0.021) + (0.004 \* ln 0.004) + (0.004 \* ln 0.004) + (0.163 \* ln 0.163) + (0.004 \* ln 0.004) + (0.067 \* ln 0.067) + (0.004 \* ln 0.004) + (0.017 \* ln 0.017) + (0.125 \* ln 0.125) + (0.079 \* ln 0.079) + (0.050 \* ln 0.050) + (0.075 \* ln 0.075) + (0.004 \* ln 0.004) + (0.004 \* ln 0.004) + (0.017 \* ln 0.017) + (0.004 \* ln 0.004) + (0.004 \* ln 0.004) + (0.004 \* ln 0.004) + (0.050 \* ln 0.050) + (0.004 \* ln 0.004) + (0.004 \* ln 0.004) + (0.004 \* ln 0.004) + (0.004 \* ln 0.004) + (0.021 \* ln 0.021) + (0.017 \* ln 0.017) + (0.008 \* ln 0.008) + (0.017 \* ln 0.017) + (0.0125 \* ln 0.0125) + (0.033 \* ln 0.033) = **3.1823**. Evenness is then EH = 3.1823 / ln 37 = **0.8813** (37 being S, the total number of species at this site). Using the same equations, Shannon's H for the banana plantation is **0.8322**, and EH = **0.3153**.

# Interpretation

We can see from our results that the diversity and evenness in this site from the undisturbed habitat (primary rain forest) are much higher than in the site from the highly disturbed habitat (banana plantation). The primary rain forest not only has a greater number of species present, but the individuals in the community are distributed more equitably among these species. In the banana plantation there are 23 fewer species and over 80% of the individuals belong to one species, *Solenopsis geminata* (the most common species in the primary rain forest, on the other hand, makes up about 16% of the community [*Pheidole* sp. 15]).

# Conclusion

Different levels of disturbance have different effects on ant diversity. If our goal is to preserve biodiversity in a given area, we need to be able to understand how diversity is impacted by different management strategies. Because diversity indices provide more information than simply the number of species present (i.e., they account for some species being rare and others being common), they serve as valuable tools that enable biologists to quantify diversity in a community and describe its numerical structure.

# Additional Questions

1. Calculate H and EH for both the abandoned and productive cacao plantation sites. Are they more similar to one another or to the more or less disturbed habitats?

2. What do you notice about the species compositions of these four habitats (i.e., do most species occur in all four habitats, in only one habitat, etc.)?

*Extra credit:* Calculate [Simpson's](http://www.tiem.utk.edu/~gross/bioed/bealsmodules/simpsonDI.html) D and ED for the primary forest and abandoned cacao plantation sites. Do these values lead to the same conclusions drawn from your calculations of Shannon's indices?

# 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.

Roth, D. S., I. Perfecto, and B. Rathcke. 1994. The effects of management systems on ground-foraging ant diversity in Costa Rica. *Ecological Applications 4*(3):423-436.

# About this Resource

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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)
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