BIODIVERSITY

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MEASURING BIODIVERSITY

Student and Teachers guide

BIODIVERSITY – MEASURING BIODIVERSITY

Biodiversity is a contraction of ‘biological diversity’ and is used to describe the variety of life. It refers to the number and variety of organisms within a particular area and has three components: **species diversity**; **ecosystem (or habitat) diversity**; and **genetic diversity**. Biodiversity is often used as a measure of the health of biological systems.

Species diversity

Species diversity relates to the number of the different species and the number of individuals of each species within any one community. A number of objective measures have been created in order to measure species diversity.

Species richness

Species richness is the number of different species present in an area. The more species present in a sample the ‘richer’ the area.

Simpson’s diversity index

Species richness as a measure on its own takes no account of the number of individuals of each species present. It gives equal weight to those species with very few individuals and those with many individuals. Thus, one daisy has as much influence on the richness of the area as 1000 buttercups.

A better measure of diversity should take into account the abundance of each species. To illustrate this, compare the data for wildflowers sampled in two different fields. Which field has greater diversity?

	Number of individuals	
Flower species	**Field A**	**Field B**
Daisy	300	10
Dandelion	330	50
Buttercup	370	940
Total	1000	1000

The species richness is the same and the total abundance is the same, but field B is dominated by just one species – the buttercup. A community dominated by one or two species is considered to be less diverse than one in which several different species have a similar abundance.

Simpson’s index (**D**) is a measure of diversity, which takes into account both species richness, and an evenness of abundance among the species present. In essence it measures the probability that two individuals randomly selected from an area will belong to the same species. The formula for calculating D is presented as:

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

where n_i = the total number of organisms of each individual species
N = the total number of organisms of all species

The value of **D** ranges from 0 to 1. With this index, 0 represents infinite diversity and, 1, no diversity. That is, the bigger the value the lower the diversity.

This does not seem intuitive or logical, so some texts use derivations of the index, such as the inverse (1/D) or the difference from 1 (1-D). The equation used here is the original equation as derived by Edward H. Simpson in 1949. Note that this equation will always be shown in a question where you are asked to calculate Simpson's index.

To calculate Simpson's index for a particular area, the area must be sampled. The number of individuals of each species must be noted. For example, the diversity of the ground flora in a woodland might be determined by sampling with random quadrats. The number of plant species in each quadrat, as well as the number of individuals of each species should be noted. There is no necessity to be able to identify all the species provided that they can be distinguished from each other. Further, percentage cover can be used to determine plant abundance but there must be consistency, either all by 'number of individuals' or all by 'percentage cover'.

Low species diversity suggests:

- relatively few successful species in the habitat
- the environment is quite stressful with relatively few ecological niches and only a few organisms are really well adapted to that environment
- food webs which are relatively simple
- change in the environment would probably have quite serious effects

High species diversity suggests:

- a greater number of successful species and a more stable ecosystem
- more ecological niches are available and the environment is less likely to be hostile
- complex food webs
- environmental change is less likely to be damaging to the ecosystem as a whole

Species biodiversity may be used to indicate the 'biological health' of a particular habitat. However, care should be used in interpreting biodiversity measures. Some habitats are stressful and so few organisms are adapted for life there, but, those that do, may well be unique or, indeed, rare. Such habitats are important even if there is little biodiversity. Nevertheless, if a habitat suddenly begins to lose its animal and plant types, ecologists become worried and search for causes (e.g. a pollution incident). Alternatively, an increase in the biodiversity of an area may mean that corrective measures have been effective.

Biodiversity at other organisational levels

Biodiversity operates at other levels also.

Ecosystem (habitat) diversity

This is the diversity of habitats or ecosystems within an area. A region possessing a wide variety of habitats is preferable, and will include a much greater diversity of species, than one in which there are few different habitats. More specifically a countryside which has ponds, river, woodland, hedgerows, wet meadowland and set-aside grassland will be more species rich and more diverse than countryside with ploughed fields, land drained and without wet areas and devoid of woods and hedgerows.

Genetic diversity

This is the genetic variability of a species. Genetic diversity can be measured directly by genetic fingerprinting or indirectly by observing differences in the physical features of the organisms within the population (e.g. the different colour and banding patterns of the snail *Cepea nemoralis*). Genetic fingerprinting of individuals within cheetah populations has indicated very little genetic variability. Lack of genetic diversity would be seen as problematic. It would indicate that the species may not have sufficient adaptability and may not be able to survive an environmental hazard. The Irish potato blight of 1846, which killed a million people and forced another million to emigrate, was the result of planting only two potato varieties, both of which were vulnerable to the potato blight fungus, *Phytophthora infestans*.

Using Simpson's index to measure biodiversity – a worked example

It may be easier to understand the use of Simpson's index with the following example. Consider three communities, each made up of a total of 100 organisms, drawn from combinations of ten species, A to J.

Community 1 has the highest diversity. It has the joint highest species richness (10) and each species has a similar relative abundance. Community 2 has the same species richness as community 1, but is dominated by one species (A) so that the diversity of this community is lower than in community 1. Community 3 has a lower diversity than community 1, due to its lower species richness.

Table 1 *Species composition of three different communities.*

Species	Community 1	Community 2	Community 3
A	10	72	35
B	9	6	34
C	11	3	31
D	10	3	0
E	8	1	0
F	12	3	0
G	10	4	0
H	11	3	0
I	10	2	0
J	9	3	0
Total	100	100	100

The formula for calculating Simpson's index is:

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

Where N = the total number of all organisms
n_i = the numbers of individuals of each individual species

The lower the value of D, the greater is the species diversity. Take for example community 1 in the table 1 above. The values of (n-1) and n_i(n-1) in the computation of D are shown in table 2 opposite.

Table 2 *Data for calculation of Simpson's index for community 1.*

Community 1			
Species	$\mathbf{n_i}$	$\mathbf{n_i - 1}$	$\mathbf{n_i(n_i - 1)}$
A	10	9	90
B	9	8	72
C	11	10	110
D	10	9	90
E	8	7	56
F	12	11	132
G	10	9	90
H	11	10	110
I	10	9	90
J	9	8	72
Total	N = 100		$\Sigma n_i(n_i - 1) = 912$

So for community 1:

$$D = \frac{912}{100 \times 99}$$

$$= 0.09 \text{ (high diversity)}$$

By the same method, the Simpson's index, D, for community 2 has been calculated and is shown in table 3 below.

Table 3 *Values for Simpson's index for communities 1, 2 and 3.*

Community	D	Level of diversity
1	0.09	Very high
2	0.52	Moderate
3		

Calculate the value of D for community 3 and insert these in the table. Show your working in the space below.

A group of students carried out some fieldwork to investigate the diversity of insects in three habitats:

- a field of barley
- a field of wheat
- the vegetation under a hedge.

Their results are shown in Table 1. Table 1 also shows how they used their data to calculate Simpson's index (D) for each habitat.

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

where N = the total number of insects found, and n_i is the number of individuals of each species.

	Number of individuals of each species in each habitat		
Species	**Barley field**	**Wheat field**	**Under hedge**
a	32	4	0
b	78	0	1
c	0	126	2
d	0	5	12
e	0	0	8
f	0	0	9
g	0	25	3
h	0	10	3
i	0	0	2
j	0	0	5
k	86	56	0
l	0	0	7
Species richness	3	6	10
Total number of insects (N)	196	226	52
Simpson's index (D)		0.39	0.14

Table 1

(a) State what is meant by the term *species richness.*

____ **[1]**

(b) (i) Calculate the value for Simpson's index (D) for the barley field.
Show your working and write your answer **in the shaded box in Table 1**.

[2]

(ii) Using the data in Table 1, suggest why the value of Simpson's index (D) for the vegetation under the hedge is much lower than that for the wheat field.

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____ **[3]**

(c) Describe how the students may have determined the numbers of individuals of each species in each habitat.

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____ **[5]**

(d) Studies of biodiversity are an integral part of an environmental impact assessment (EIA).

(i) Discuss the role of an EIA as part of a local planning decision.

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____ **[3]**

(ii) Suggest why some conservationists might object to these studies.

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____ **[2]**

Total: [16]