Section IV

Diversity and Feeding Ecological Studies

Chapter 8

Diversity Indices

8.1 What is Diversity

Diversity is the degree of heterogeneity in a community. The purpose of measuring diversity in an ecosystem is to judge the relationship of a community to its own members and also to other community properties (e.g. productivity) or to prevailing environmental conditions (Pielou, 1975). High taxon (e.g. species) diversities are related to high community composition, high environmental stability, high environmental predictability and high productivity. It is claimed as an effective statistics to understand and to predict a changed environment (Wilhm and Dorris, 1968; Cairns and Dickson, 1971).

8.2 Indices for Diversity Measures

Diversity can be measured using diversity measures or indices. Diversity indices are mathematical functions that combine richness and evenness in a single measure. These indices provide information about community composition rather than simply explaining the richness of a community. Most diversity indices are easy to compute and are widely used for community as well as ecosystem assessment.

Species diversity or α-diversity is measured in species level (Mc Arthur, 1964). However it can be measured upto any taxonomic unit. The species diversity measures included here are:

(i) Species richness

(ii) Relative Comparison Index

(iii) Shannon-Weaver diversity index

(iv) Simpsons' diversity index
(v) Margalef's diversity index
(vi) Berger-parker index

8.2.1 Species Richness(s)

The number of species in a community or ecosystem is called richness. It is the simplest of all diversity indices and gives only the number of species present irrespective of their distribution or evenness. However, chances are there for biasness if richness is considered since all species, especially animals in an area cannot be counted during the time of sampling.

However, other diversity indices like Shannon-Weaver or Simpson combine richness and evenness (homogeneity) to a single measure.

8.2.2 Relative Comparison Index (Saikia and Das 2012)

Relative Comparison Index (CI) is a rapid method of comparing planktonic communities on a gradient (e.g. temporal, spatial etc.). This index assuming '1' for every absence data in a sample, instead '0' (which is adopted in most of other indices) while comparing with other samples of same environment. The advantage over such assumption in relative CI is that it makes the comparison more sensible than other indices with less sensibility when results are on the basis of virtual presence or absence of the taxon in the sample. An explanation on how to compute this index is given in Table 3. The table displays phytoplankton records of five sampling dates, e.g. Day A, Day B, Day C, Day D and Day E. On day A (p=A), the measure M_A/n_{iA} reveals the comparative value of plankton abundances to other samples (i.e. upto M_E/n_{iE}) on monocaculative terms. The value for ratio M_A/n_{iA} where p=A has been termed as Comparison Index (CI).

For sample p, mathematical expression of CI is,

$$\mathrm{CI_p} = \mathrm{M_P}/\textstyle\sum \mathrm{n_{ip}} \tag{1}$$

or simply,

$$\log \mathrm{CI_p} = \log \mathrm{M_P} - \log \textstyle\sum \mathrm{n_{ip}} \tag{2}$$

where $\sum n_{ip}$ is total count of i^{th} taxon employing '1' for each absence event in sample p ($\sum n_{ip}$ >0). In table 3, p = A or B or C or D or E. The $M_p = N_p - \sum n_{ip}$ with N_p as total overall count of taxa present employing '1' for each presence event of a taxon in overall sample.

To make CI as more justified ecological index, an explanation of evenness in the sample can also be counted as log CI.

The evenness values based on CI (or E_{CI}) from *p* sample was computed out as

$$E_{CIp} = \log CI_p/2 \text{ or } \log M_P - \log \sum n_{ip}/2 \quad (3)$$

where $\sum n_{ip}$ is total count of i^{th} taxon employing '1' for each absence event in sample *p* and $M_p = N_p - \sum n_{ip}$ with N_p as total count of taxa present employing '1' for each presence event of a taxon in overall sample.

***Table 3.** Calculation of relative comparison index (Saikia and Das 2012).*

N	A	B	C	D	E
1	Scenedesmus	Scenedesmus	Scenedesmus	1	1
2	Pediastrum	1	1	Pediastrum	Pediastrum
3	Oedogonium	Oedogonium	Oedogonium	1	Oedogonium
4	Euastrum	Euastrum	1	1	1
5	Closterium	Closterium	Clsterium	1	1
6	Pleurotaenium	1	Pleurotaenium	Pleurotaenium	1
7	Cylindrocapsa	1	Cylindrocapsa	1	1
8	Closteriopsis	Closteriopsis	Closteriopsis	Closteriopsis	Closteriopsis
9	Cosmarium	Cosmarium	Cosmarium	Cosmarium	Cosmarium
10	Micrasteria	1	Micraseria	1	1
11	Euglena	Euglena	Euglena	1	1
12	1	Docidium	1	1	1
13	1	Macrospora	Microspora	1	Microspora
14	1	Ankistrodesmus	1	Ankistrodesmus	Ankistrodesmus
15	1	Ankistrodesmus	1	Tetraspora	1
16	1	Tetraspora	1	Chlorella	1
17	1	Chlorella	1	Staurastrum	Staurastrum
18	1	Staurastrum	Mesotaenium	1	1
19	1	1	Actinotaenium	1	1
20	1	1	Gonatozygon	1	1
21	1	1	1	1	Geminella
22	1	1	1	1	Hormidium
23	1	1	1	1	Zygnema
n_{ip}	12	09	10	15	13
M_p	11	14	13	8	10
CI_p	0.9167	1.5556	1.3	5.3333	0.7692
$\log CI_p$	-0.03779	0.19189	0.11394	-0.273	-0.11394

The graphical presentation for CI is shown in Fig 5.

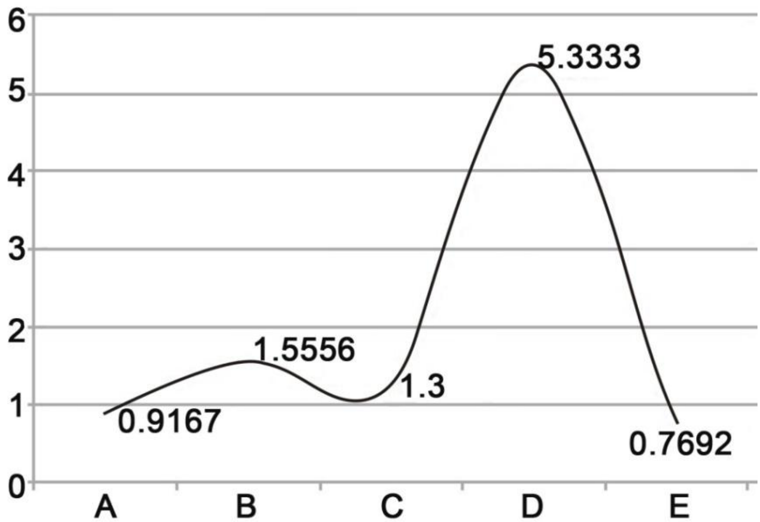

Fig. 5. *Graphical presentation of CI on temporal gradients. The minor differences of planktonic richness on different sampling dates (e.g. B and C) are prominent.*

8.2.3 Shannon-Weaver diversity (Shannon 1948, Shannon-Weaver 1949)

This is one of the most commonly used measures of species diversity. It accounts the relative abundance and evenness of a species in the community.

The measure is based on two information:

(1) the number of species (i.e. richness) and

(2) The number of individuals in each species

The index is used only on random samples drawn from a large community in which the total number of species is known.

$$H = -\sum_{i=1}^{s} Pi \ln Pi \quad \text{where } Pi = ni / N$$

Here,

H is Shannon-Weaver species diversity.

ni is the total number of individual of species.

N is the total number of all species in stand.

S is the number of species in the sample.

BOX 4

Calculation of H

The following table is prepared from plankton diversity from a freshwater pond.

Sl no.	Name of organism	individual count (ni)	ni/N	ln(ni/N)	ni ×ln(ni/N)
1	*Scenedesmus sp.*	22	0.0503	-2.9889	-0.1505
2	*Pediastrum sp.*	56	0.1281	-2.0546	-0.2633
3	*Oedogonium sp.*	36	0.0824	-2.4964	-0.2057
4	*Spirogyra sp.*	10	0.0229	-3.7773	-0.0864
5	*Bulbochaete sp.*	4	0.0092	-4.6936	-0.0430
6	*Closterium sp.*	26	0.0595	-2.8218	-0.1679
7	*Chlorella sp.*	18	0.0412	-3.1896	-0.1314
8	*Pleurotaenium sp.*	60	0.1373	-1.9856	-0.2726
9	*Triplocera sp.*	20	0.0458	-3.0842	-0.1412
10	*Xanthidium sp.*	14	0.0320	-3.4409	-0.1102
11	*Cosmarium sp.*	10	0.0229	-3.7773	-0.0864
12	*Staurastrum sp.*	8	0.0183	-4.0005	-0.0732
13	*Gonatozygon sp.*	30	0.0686	-2.6787	-0.1839
14	*Mesotaenium sp.*	25	0.0572	-2.8611	-0.1637
15	*Euastrum sp.*	98	0.2243	-1.4950	-0.3353
	S=15	N = 437		∑2.4146	

Theoretical maximum value of

$$H = \ln(S) = \ln(15) = 2.70805$$

Theoretical minimum value of

$$H = \ln[N/(N-S)] = \ln[437/(437-15)] = 0.03493$$

Calculated H from

$$\text{data} = -\sum pi \ln pi \text{ or } -\sum ni/N \ln ni/N = -(-2.4146) = 2.4146$$

Comment

As calculated H is nearer to theoretical maximum value of H, the diversity in the pond can be said high.

(1) Interpretation

1. H increases with the number of species (i.e. richness) in the community. However, increasing the number of species in a community will not necessarily increase diversity.
2. More complex the community, the greater is the species diversity and stability (Mc Arthur, 1965).
3. When diversity is studied in a time scale, greater the function in H, less is its stability.
4. High diversity when there is no numerically dominant species.
5. Shannon-Weaver diversity index is less sensitive to rare species.

(2) Comment

- In practice, for biological communities H does not seem to exceed 5.0 (Washington, 1984). The theoretical maximum value is ln(S), and the minimum value in ln[N/(N-S)] (Fager, 1972).
- At least 10 replications are to be analyzed.

8.2.4 Simpson's Diversity Index (D) (1964)

Simpson's diversity index (D) can be measured for finite and infinite population. Simpson diversity is less sensitive to richness than to evenness.

(1) D for Finite Population

A finite population is a population in a closed ecosystem. It can be measured as:

$$D = 1 - \sum_{i=1}^{S} \left[\frac{ni\,(ni-1)}{N\,(N-1)} \right] \quad (\text{Pielou}, 1969)$$

(2) D for Infinite Population

$$D = 1/\sum ni/N$$

Here,

ni = Number of individual species.

N = Total number of species.

BOX 5

The following table is prepared from plankton diversity from a freshwater pond (finite population).

Sl no.	Name of organism	individual count (ni)	ni-1	ni(ni-1)	ni(ni-1)/N(N-1)
1	*Scenedesmus sp.*	22	21	462	0.0024
2	*Pediastrum sp.*	56	55	3080	0.0162
3	*Oedogonium sp.*	36	35	1260	0.0066
4	*Spirogyra sp.*	10	9	90	0.0005
5	*Bulbochaete sp.*	4	3	12	0.0000
6	*Closterium sp.*	26	25	650	0.0034
7	*Chlorella sp.*	18		306	0.0016
8	*Pleurotaenium sp.*	60	59	3540	0.0186
9	*Triplocera sp.*	20	19	380	0.0020
10	*Xanthidium sp.*	14	13	182	0.0010
11	*Cosmarium sp.*	10	9	90	0.0005
12	*Staurastrum sp.*	8	7	56	0.0003
13	*Gonatozygon sp.*	30	29	870	0.0046
14	*Mesotaenium sp.*	25	24	600	0.0031
15	*Euastrum sp.*	98	97	9506	0.0499
	N = 437		N-1=436		0.1107

Here, N(N-1) = 190532

Simpson D = 1-∑[ni(ni-1)/N(N-1)] = 1.0000-0.1107 = 0.8893

Maximum value of D = 1- (1/S)= 1-(1/15) = 0.9333

(3) Interpretation

1. Simpson's index ranges from 0 to 1.0.
2. 0 diversity, when community complexity is less and 1 diversity when community complexity is high.
3. Low diversity (near to 0) indicates presence of dominant species or taxa, high diversity (near to 1) indicates presence of all constituent taxa in more or less uniform state.

(4) Comment

Simpsons' index is most sensitive to the changes in the more abundant species.

8.2.5 Margalef's Diversity Index, 1968

This index is used for small samples. It can be measured as:

$$H = S\text{-}1/\text{InN}$$

Here,

H = Margalef's index

S = Number of species

N = Total number of individuals

8.2.6 McIntosh Diversity Index

It was suggested by McIntosh in 1967. The values are between 0 – 1. When the value is getting closer to 1, it means that the organisms in a community are homogeneously distributed (McIntosh 1967).

$$Mc = [\ N - \sqrt{(\sum ni^2)}\ ] \ / \ [\ N - \sqrt{N}\ ]$$

Here,

Mc = McIntosh Diversity Index

ni = Number of individuals belonging to species i

N = Total number of individuals

8.3 Indices for Evenness Studies

Evenness measure represents the equitability of species in a community. A measure of evenness is supportive for the diversity index. Lloyed and Ghelardi (1964) suggested to measure the evenness component separately for the study of diversity. The two highly popular evenness measures are:

(i) Shannon-Weaver evenness measure.

(ii) Simpson's evenness measure or Evenness measure based on D.

8.3.1 Shannon-Weaver Evenness Measure (J) (Pielou, 1966)

It is calculated on the basis of H value.

$$J = H / H_{max}$$

Here,
H = Shannon-Weaver index
H_{max} = Maximum value of H. $H_{max} = \ln S$

For example, in BOX 4, the H is 2.4146 and H_{max} is 2.70805. Therefore, J = 2.4146/2.70805 = 0.8916 which reflects the species are more or less equally homogenous distribution in the pond environment at the time of sampling.

8.3.2 Simpsons' Evenness Measure (E)

It is calculated on the basis of D value.

$$E = D / D_{max}$$

Here,
D = Simpsons' diversity index
D_{max} = Maximum possible value of Simpsons' diversity. $D_{max} = 1/S$.

From BOX 5, D is 0.8893 and Dmax is 0.9333. Hence, E = 0.8893/0.9333 = 0.9528 which indicates more or less equal distribution of species in pond environment at the time of sampling.

(1) Interpretation

(i) Low evenness value indicates less equitability among the species, high evenness value indicates equal distribution of species.
(ii) Less evenness value indicates dominance of a single species in the community.

(2) McIntosh Evenness Index

It was derived from McIntosh index. The values are between 0 – 1. When the value is getting closer to 1, it means that the individuals are distributed equally (Heip and Engels 1974).

$$McE = [\ N - \sqrt{(\sum ni^2)}\ ] / [\ N - (N / \sqrt{S})\ ]$$

Here,
McE = McIntosh evenness index

ni = Number of individuals belonging to i species

S = Total number of species

N = Total number of individuals

8.4 Dominance Index

It gives the magnitude of dominance of a species in a community. Two popular dominance indices are:

1. Concentration of dominance.
2. Berger-Perker dominance index.

8.4.1 Concentration of Dominance (C)

It is the most common and easiest index to calculate. It is calculated as:

$$C = (Ni/N)^2 \text{ (Odum, 1971)}$$

Here

Ni = the total number of individuals of species and

N = the total number of individuals of all species in a stand.

8.4.2 Berger-Perker Index (d) (1970)

It is calculated as:

$$d = N_{max}/N$$

Here

N = total number of individuals of all species in a stand

N_{max} = Maximum number of species counted.

8.5 Variety Index (V)

Variety index helps in comparing one community or group of population with another. It is calculated as:

$$V = S/InN^* \text{ (Odum, 1971)}$$
$$\text{(*Odum used } \log_2\text{)}$$

Here

S = Number of species recorded

N = total number of individual recorded

8.6 Similarity and Dissimilarity Indices

8.6.1 Similarity Index

Similarity index helps in understanding the diversity level of two ecosystems. It indirectly indicates the magnitude of similarity and dissimilarity of the environmental conditions of two different ecosystems.

The similarity index can be computed according to Sorensen (1948).

$$SIMI = 2C/ A+B$$

Here

A and B are the number of taxa recorded to different ecosystems,

C is the number of taxa common to A and B ecosystems.

8.6.2 Index of Dissimilarity (DI)

$$DI = 1\text{-}SIMI$$

(1) Comment

The values of SIMI and DI are generally expressed in terms of percentage.