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Comparative Analysis of Diversity and Similarity Indices with Special Relevance to Vegetations around Sewage Drains

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***Abstract*—**Indices summarizing community structure are used to evaluate fundamental community ecology, species interaction, biogeographical factors, and environmental stress. Some of these indices are insensitive to gross community changes induced by contaminants of pollution. Diversity indices and similarity indices are reviewed considering their ecological application, both theoretical and practical. For some useful indices, empirical equations are given to calculate the expected maximum value of the indices to which the observed values can be related at any combination of sample sizes at the experimental sites. This paper examines the effects of sample size and diversity on the expected values of diversity indices and similarity indices, using various formulae. It has been shown that all indices are strongly affected by sample size and diversity. In some indices, this influence is greater than the others and an attempt has been made to deal with these influences.

***Keywords*—**Biogeographical factors, Diversity Indices, Ecology and Similarity Indices

I. Introduction

FOR many years, environmental variables and indices have been used to monitor pollution, changes in biotic communities and so-called 'environmental standards' or 'quality of the environment'. Environmental indices include those that are based on physical and chemical parameters, those based on biological parameters and also those based on perceived aesthetic qualities of the environment. The use of structural indices to measure fundamental community parameters associated with species abundance and community composition and to assess changes in biological communities due to environmental stress has long been an important aspect of theoretical and applied ecological research [9], [11]. Community structure is a diverse and well developed field. They range from studies from mathematical basis for some metrics of community structure to comparative analysis of diversity indices and similarity indices. Mc Arthur and Lewis suggested that species diversity is a statistical abstraction having two components – one reflecting the number of species (richness) and other is distribution of individual of all species at a particular site [1], [2]. The effect of sample size and species diversity on a variety of similarity indices is explored.

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Real values of a similarity index must be evaluated relative to the expected maximum value of that index, which is the value obtained for samples randomly drawn from the same universe, with the diversity and sample sizes of the real samples [8]. To interpret a given value of a similarity index one must compare it with its maximum value. At that maximum value, one usually takes the theoretical maximum value, which is the value obtained when comparing two identical samples.

II. Materials And Methods

The entire experimental area is situated around three sewage drains (site I, II & III) in the municipal area of Jaunpur (India). Plants were identified randomly and demarcated by using quadrates of 50 x 50 cm on the study sites (I, II and III) at bimonthly intervals. Number of individual of each species and total number of plants were recorded. Best fit diversity indices were used [9].

The diversity indices of plant community were computed on the basis of density values or total number of individuals of the plants on all the three study sites (I, II and III) during summer, winter and rainy seasons. Seven different indices for describing the species diversity have been devised by various scientists:

i) The Simpson's index D [7] is calculated by the formula:

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

where, n_i = Number of individuals of i[th] species, and N = Total number of individuals of all species.

ii) The Shannon and Weaner index (H') is computed from the formula as modified by Shannon and Weaner [3]:

$$H' = -3.3219 \sum \frac{n_i}{N} \log\left(\frac{n_i}{N}\right)$$

where, n_i = Number of individuals of i[th] species, and N = Total number of individuals.

iii) The Evenness (E) is computed from Pielou's index [13].

$$E = H' / In\, S$$

where, H' = Shannon – Weaner diversity, and $In\, S$ = Natural log of the total number of species recorded.

iv) The concentration of dominance (Cd) is calculated by using the formula given by Simpson [7]:

$$Cd = (N_i / N)^2$$

where, N_i = Proportion of individuals belonging to the ith species, N = Total number of individuals.

v) Margalef's community diversity index is calculated by using the following formula given by Margalef [6]:

$$d = S - 1/\log N$$

where, S = Total number of species, and N = Total number of individuals.

vi) Mc Intosh diversity Index is calculated by using the formula given by Mc Intosh [5]:

$$DI = \sum \sqrt{S \cdot n_i^2}$$

where, S = Total number of species, and n_i = Number of individuals of ith species.

vii) Menhinick diversity Index is calculated by using the formula given by Menhinick [4]:

$$d = S/\sqrt{N}$$

where, S = Total number of species, and N = Total number of individuals.

viii) Similarity Index (SI): Similarity Index determines the interspecific association between the species of plant communities. Similarity Index (SI) is calculated by using the formula given by Sorensen [14]:

$$\text{Similarity Index } (SI) = \frac{2D}{A + B + C}$$

where, D = No. of species common to the three study stand,
A = No. of species on stand A,
B = No. of species on stand B, and
C = No. of species on stand C

ix) Dissimilarity Index (DI): Dissimilarity Index is the reverse sequence of similarity index. It is calculated by the formula:

$$DI = 1 - SI$$

where, SI = Similarity Index

TABLE I
SEASONAL VARIATION IN DIVERSITY INDICES OF PLANT COMMUNITY AT THREE STUDY SITES (I, II AND III)

Diversity index	Summer Season			Rainy Season			Winter Season			Average		
	I	II	III	I	II	III	I	II	III	I	II	III
Simpson	0.56	0.52	0.46	0.49	0.32	0.40	0.28	0.34	0.25	0.44	0.39	0.37
Shannon-Weaner	2.45	2.34	2.28	2.40	1.98	2.05	3.14	2.54	2.31	2.66	2.29	2.21
Evenness	0.33	0.31	0.30	0.27	0.22	0.24	0.37	0.30	0.27	0.32	0.28	0.27
Concentration of dominance	0.35	0.35	0.32	0.22	0.30	0.16	0.34	0.20	0.19	0.30	0.28	0.22
Marglef's	12.30	12.01	11.58	10.29	10.06	10.40	10.57	10.72	10.47	11.05	10.93	10.81
Mc Intosh	5075.1	4021.1	3144.2	2315.3	1865.2	1648.2	2499.3	2043.2	1946.72	3296.58	2643.21	2246.40

III. RESULT AND DISCUSSION

The attributes of seasonal variation in diversity indices of the three study sites are depicted in Table 1. Species diversity affords stability to ecosystem. The Simpson index value at sites I, II and III ranged from 0.25 to 0.56. The value at site I was 0.56, 0.49 and 0.28; at site II 0.52, 0.32 and 0.34, and at site III it was 0.46 and 0.40 and 0.25 in summer, rainy and winter season, respectively. The average value was maximum at site I (0.44) and minimum at site III (0.37). The Shannon-Weaner function values were maximum during winter season at all the three sites I, II and III, i.e., 3.14, 2.54, and 2.31, respectively. In contrast, the lowest values were during rainy season, i.e. 2.40, 1.98 and 2.05 (site I, II and III, respectively).

The average was maximum at site I (2.66) and minimum at site III (2.21). The peak value of evenness at site I was 0.37 (winter), at site II it was 0.31 (summer) and at site-III it was 0.24 (rainy). The average value was maximum at site I (0.32) and minimum at site-III (0.27).

The concentration of dominance was maximum during summer season at the sites, I, II and III, i.e., 0.35, 0.35 and 0.32, respectively. It was minimum in rainy season at site I (0.22) and at site III (0.16); and at site II (0.20) it was lowest in winter. The average value at site I, II and III was 0.30, 0.28 and 0.22, respectively. Marglef's index has peak values of 12.30, 12.01 and 11.58 at sites I, II, and III, respectively during the summer season. The corresponding lowest values of were found during rainy season, i.e. 10.29, 10.06 and 10.40 at sites I, II and III, respectively.

The average values were maximum at site I (11.05) and minimum at site III (10.81).

The Mc Intosh index values were maximum during summer (5075.13, 4021.15, and 3144.25) at the three sites I, II and III, respectively. The minimum values were again in rainy season (2315.32, 1865.28 and 1648.24) at the three sites I, II and III, respectively. The average values were maximum 3296.58 (site I) and minimum 2246.40 (site III).

Maximum values for Menhinick index were 1.04, 0.95 and 0.82 in summer season at the study sites I, II and III, respectively. Their respective minimum values were 0.51, 0.46 and 0.46, with the average value of 0.69, 0.67 and 0.63 of site I, II and III, respectively.

Similarity index along with the respective dissimilarity index was also calculated and is indicated in Table 2. Similarity index was maximum during rainy season (0.59), followed by the value during winter season (0.52) and minimum during summer season (0.48). On the whole the value always remained less than unity.

TABLE II
SIMILARITY AND DISSIMILARITY INDEX IN DIFFERENT SAMPLING MONTHS AT THE THREE SITES (I, II AND III)

Season	Similarity Index	Dissimilarity Index
Summer	0.48	0.52
Rainy	0.59	0.41
Winter	0.52	0.48

The result of this investigation reveals that species diversity is useful parameter for the comparison of communities under the influence of biotic disturbances or to know the state of succession and stability in the community. It is clear from diversity indices of plant community that site I shows greatest species diversity in comparison to site II and III. Site II lies next to it and site III is the least one. Shannon-Weaner index is controlled by equitability (evenness) than by species richness [10], [12]. In the present investigation, evenness was maximum at site I and minimum at site III. Maximum concentration of dominance at site I reflects the dominance of few species only. The result indicates that Marglef's and Mc Intosh diversity values were highest at site I and lowest at site III. The Simpson diversity index is also highest at site I and lowest at site III. Dissimilarity is reverse sequence as compared to the similarity index. More or less uniform environmental conditions are revealed by higher value of similarity index, in contrast lower value indicates distinct heterogeneity. In rainy season the value of similarity index was maximum, due to high moisture content in soil, comparatively low temperature, bright light and higher organic content through humification which mostly bring about uniformity in the weather conditions. On the other hand, minimum value in summer season indicates higher heterogeneity in climatic conditions which results poor plant growth.

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