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# Determination of Ecological Diversity Indices to Assess the Interrelationship between Earthworm Diversity and Different Habitats of Indian Botanic Garden, Howrah, India

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**ABSTRACT: Diversity of earthworms was studied in five varied habitats differing in the type of plantation in the field in the Indian Botanic Garden in Howrah, India. It is a unique huge National Botanic Park rich in plant biodiversity with global variety. Twelve species of earthworms identified belonging to seven genera and three families out of a total of 911 individuals collected. *Metaphire posthuma* was the dominant species among all and was present at all the study sites. The rarest species was *Metaphire houlleti* available only at the flower garden. Analysis of different Diversity Indices values revealed that maximum species diversity in terms of diversity indices such as Shannon-Wiener index and Simpsons index were found in flower garden (Shannon H´= 0.707; Simpson 1/D = 3.701), while minimum diversity at GBT (H´= 0.414 and 1/D =1.79). Values of Margalef's index (M = 5.272) and Shannon Evenness Index (J' = 0.729) were found highest at Conifer plantation area. The species dominance in terms of Berger-Parker Dominance was maximum at GBT (d=0.734) and lowest at Flower Garden (d = 0.459). The study indicates the richness of earthworm diversity in the study site in Indian Botanic Garden, Howrah.**

**Key words**: Earthworm, diversity, botanic garden, diversity indices, Howrah, West Bengal.

## INTRODUCTION

Earthworms are the moist soil dwelling creatures, which make up a large part of total biomass of invertebrates of soil (Soulsby, 1982). They are the members of the class Oligochaeta of Phylum Annelida (Edwards, 2004). Earthworms in the soil act as aerators, grinders, crushers, chemical degraders and biological stimulators (Edwards and Bohlen, 1996) and regulate the soil processes (Ismail 1997). They are found in all types of soils with sufficient moisture and food (Ghosh,1993).They consume soil organic matter and litter thereby increasing availability of plant nutrients in their casts (Brown *et al*, 2004) and so used as indicator of the health of soil ecosystems (Edwards and Bohlen, 1996) due to their role in soil fertility through fragmentation and mixing of soil with mineral particles. As ecosystem engineers, earthworms can directly affect the availability of resources to other organisms through modification of the physical environment (Lavelle *et al*., 1997).

India is one of the seventeen mega diverse countries of the World and owes its position in the tropical and subtropical latitudes. Worldwide more than 4,400 species of earthworms have been reported (Sinha 2009). The Indian earthworm fauna is predominantly composed of native species, which constitute about 88.8% of total earthworm diversity in the country (Julka and Paliwal, 2005). Julka *et al*. (2009) reported 590 species of earthworms from India. Though the area of India is only 2% of the world's total landmass, it harbours about 11.1% of the global earthworm diversity (Tripathi and Bhardwaj 2004).

Earthworm diversity and distribution pattern are generally governed by a variety of biotic and abiotic factors such as soil properties, surface litter, vegetation type and its dynamics, land use pattern, local or regional climate and pressure of human activities (Decaëns *et al.* 1998, 2008b; Decaëns 2010; Suthar 2011; Tondoh *et al*. 2011). Due to their relationship to soil ecosystem function, earthworm population structure may be influenced by a change in vegetation and soil characteristics, as well as biotic and abiotic interactions (Margerie *et al.* 2001; Whalen 2004; Fey 2010; Valckx *et al.* 2011). From one vegetation type to the other, earthworm species composition may change (Margerie *et al.* 2001).

A number of researchers have confirmed and documented the biodiversity study of earthworms in various parts of the world (Tsai *et al.*,1999 & 2000; Blakemore, 2000, 2002, 2003; Chang and Chen, 2004, 2005; Blakemore *et al.*, 2006; Sautter *et al*., 2006; Julka *et al*., 2009) mentioning soil diversity is important in order to sustain the ecosystem processes. Naeem *et al*.,1995 examined experimentally the association between species diversity and ecosystem processes in a series of terrestrial mesocosms. In these studies with direct manipulation of diversity under controlled environmental conditions showed the evidence that ecosystem processes affected positively by the incline of animal species diversity.

The present study site, the Indian Botanic Garden (IBG) have traditionally enjoyed virtually free and open access to plant material for their collections from any part of the world. This National botanic park is unique because of its varied diversity in its natural ecosystem that is immensely rich in plant biodiversity and soil fauna diversity. So the habitats of this botanic garden are homes to some of the world's richest and unique plants, resulting in a high diversity of earthworms. There is perhaps no record of studies pertaining to the diversity and distribution of earthworm species in this huge national garden. Hence, an attempt has been made in this study to conduct a survey of earthworm species available in the selected habitats with the following objectives; to record different earthworm species present in various habitats of IBG, to evaluate variations of earthworm diversity in terms of species richness and dominance, to assess the interrelationship between the habitat and species diversity.

## MATERIALS AND METHODS

*A. Earthworm Sampling*

The study was carried out on monthly basis for a period of one year. A sampling grid (20 m × 20 m) was marked at each site, containing 16 units of 5 m × 5 m, which were further divided into subunits of 1 $m^2$. These 1 $m^2$ subunits were selected randomly and no subunit was sampled twice. During each sampling month, for each study site three widely separated subunits were randomly selected for sampling. Earthworms were collected by conventional digging (25cm × 25cm × 30 cm) and hand sorting method (Anderson and Ingram , 1993) from each quadrat. Earthworms were counted and narcotized by dropping them in 70% ethyl alcohol. They were removed from alcohol after their movement stopped. Then worms were transferred to 10% formalin for fixation and identification. A label with site name, plot number, date is to be affixed to each vial. Abiotic factors like soil temperature, soil moisture and pH values recorded at the time of collection.

*B. Data Analysis*

Ecological indices were calculated for IBG using standard methods (Odum, 1971; Peet, 1974; Causins, 1991; Zar, 1999; Magurran, 2004). A Shanon-Wiener Diversity Index (Ludwig and Reynolds, 1988) was calculated using the formula, $H' = -\sum p_i \ln p_i$, where $p_i$ is the relative abundance of the species ($p_i = n_i/N$; $n_i$ is the number of individual species, N is the total number of individuals). Simpson's index using formula, $D = \sum n_i (n_i-1)/N(N-1)$ and Margalef Index using formula, M = (S-1) / ln N, where S: Total number of species; N: Total number of individuals. For better logical justification, inverse Simpson's diversity index (1/D) is used. Statistical analysis was done by using SPSS version 16.0 program for Windows. Shannon Wiener Index of Diversity ($H^{/}$), Evenness Index ($J^{/}$) and Berger–Parker Index of Dominance (d) were calculated by Biodiversity professional version 2 for Windows.

*C. Study Area*

The Indian Botanic Garden has been chosen as the study area which covers an area of about 273 acres on the west bank of river Ganges in West Bengal, India. The garden is scientifically planned, and plants of the same group are grown together. The garden is divided into 25 sections, each specified for growing different types of plants. Five distinctly different habitats are chosen for conducting the present study:

- Bamboo habitat
- Keora (Pandanus) habitat
- Conifer habitat
- Flower Garden
- The Great Banyan Tree region (GBT).

## RESULTS

A total of twelve species identified as belongs to seven genera under three families (Megascolecidae, Octochaetidae, Moniligastridae) are found from 911 examples of earthworms collected from Indian Botanic Garden, Howrah of West Bengal are presented in Table 1.

**Table 1: Systematic position of earthworm species present in IBG.**

| Order | Family | Genera | Species |
|---|---|---|---|
| Haplotaxida | Megascolecidae | *Amynthas* | *alexandri* Beddard |
| | | *Lampito* | *mauritii* Kinberg |
| | | *Metaphire* | *anomala* (Michaelsen) |
| | | | *houlleti* (Perrier) |
| | | | *peguana* (Rosa) |
| | | | *posthuma* (Vaillant) |
| | | *Perionyx* | *excavatus* Perrier |
| | | | *simlaensis* (Michaelsen) |
| | Octochaetidae | *Dichogaster* | *bolaui* (Michaelsen) |
| | | *Eutyphoeus* | *incommodus* (Beddard) |
| | | | *orientalis* (Beddard) |
| Moniligastrida | Moniligastridae | *Drawida* | *nepalensis* Michaelsen |

Only three species, viz., *Metaphire posthuma, Metaphire peguana, Drawida nepalensis* occur in abundance in most of the areas. *Perionyx excavatus, Amynthas alexandri* and *Eutyphoeus orientalis* are also found in four habitats,i.e. except one habitat they occur in most of the areas. In contrast, three earthworms are very site specific species such as *Metaphire houlleti* and *Dichogaster bolaui* in the Flower garden and *Perionyx simlaensis* in Bamboo habitat. Habitat wise distribution of different species of earthworms in IBG is presented in Table 2. Among the species *Metaphire posthuma, Metaphire peguana, Drawida nepalensis* are common across all the habitats. Out of these twelve species *Metaphire posthuma* is the dominant (n = 515), second ranking is *Metaphire peguana* (n = 151) and third in rank is *Drawida nepalensis* (n = 74). *Metaphire houlleti* (n = 1), *Dichogaster bolaui* (n = 2) in the Flower garden and *Perionyx simlaensis* (n = 4) in Bamboo habitat showed exclusive inhabitation. While *Perionyx excavatus* (n = 56), *Amynthas alexandri* (n = 16), *Eutyphoeus orientalis* (n = 58) are the most common species found in four habitats. *Lampito mauritii* (n = 18), *Metaphire anomala* (n = 6), *Eutyphoeus incommodus* (n = 10) are the rare ones and found only in two habitats. Different Ecological diversity indices were calculated in order to assess the interrelationship between habitat and earthworm diversity in IBG. The annual species diversity index, evenness, dominance and richness of earthworms in IBG, Howrah were analysed using the indices of Shannon-Wiener diversity index (H´), Simpsons diversity index (1/D), Shannon-Wiener evenness index (J). These indices were used to compare the diversity of earthworms among sites. The species dominance is calculated with the help of Berger-Parker Dominance(d).

**Table 2: Earthworm population in different habitats.**

| | Bamboo | Keora | Conifer | Flower garden | GBT | Total |
|---|---|---|---|---|---|---|
| *Amynthas alexandri* | 0 | 3 | 10 | 1 | 2 | 16 |
| *Lampito mauritii* | 0 | 0 | 0 | 15 | 3 | 18 |
| *Metaphire anomala* | 4 | 2 | 0 | 0 | 0 | 6 |
| *Metaphire houlleti* | 0 | 0 | 0 | 1 | 0 | 1 |
| *Metaphire peguana* | 20 | 40 | 59 | 27 | 5 | 151 |
| *Metaphire posthuma* | 110 | 137 | 37 | 79 | 152 | 515 |
| *Perionyx excavatus* | 9 | 35 | 3 | 9 | 0 | 56 |
| *Perionyx simlaensis* | 4 | 0 | 0 | 0 | 0 | 4 |
| *Dichogaster bolaui* | 0 | 0 | 0 | 2 | 0 | 2 |
| *Eutyphoeus incommodus* | 0 | 0 | 0 | 6 | 4 | 10 |
| *Eutyphoeus orientalis* | 3 | 0 | 3 | 28 | 24 | 58 |
| *Drawida nepalensis* | 28 | 15 | 10 | 4 | 17 | 74 |
| Total | 178 | 232 | 122 | 172 | 207 | 911 |

**Table 3.**

| Index | Bamboo | Keora | Conifer | Flower garden | GBT |
|---|---|---|---|---|---|
| Shannon H' Log Base 10. | 0.532 | 0.51 | 0.567 | 0.707 | 0.414 |
| Shannon $H_{max}$ Log Base 10. | 0.845 | 0.778 | 0.778 | 1 | 0.845 |

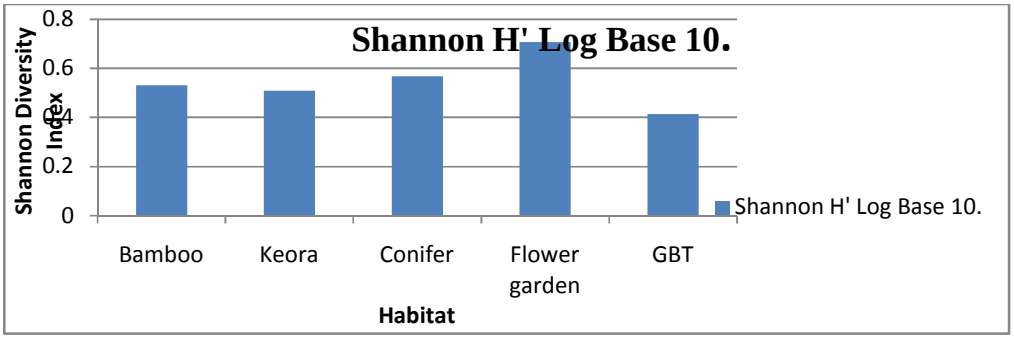



**Fig. 1**. Shannon diversity index of earthworms at different habitats.

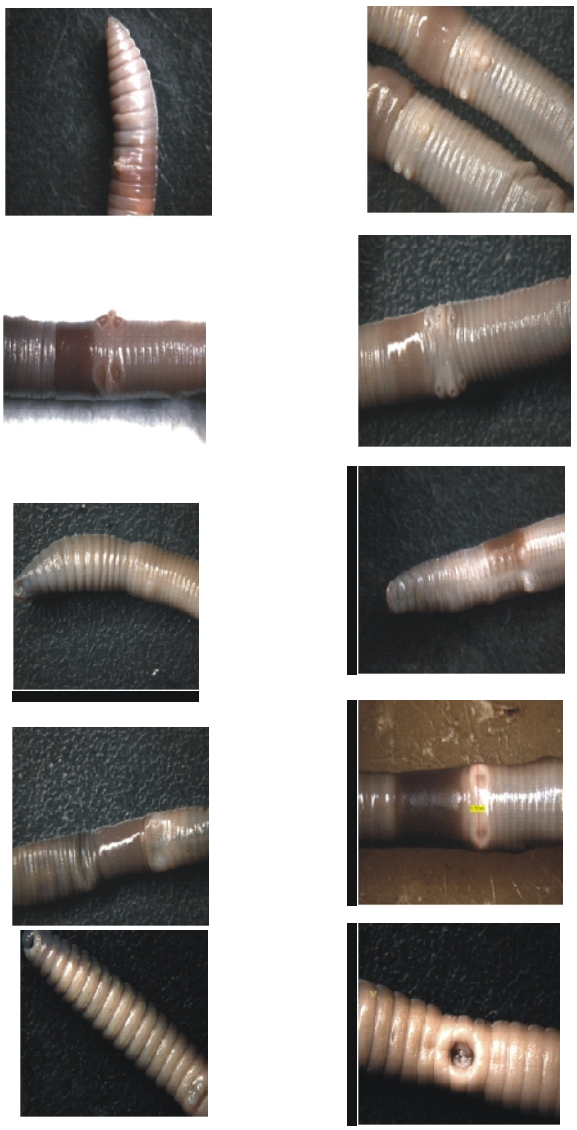


**Plate-1.** Earthworm of Indian Botanical Garden- *Drawida nepalensis, Metaphire anomala, Metaphire peguana, Metaphire posthuma, Lampito mauritii, Eutyphoeus incommodus, Metaphire houlleti, Amynthas alexandri, Perionyx excavatus, Perionyx simlaensis.*

**Shannon diversity index of earthworms at different habitats:** Shannon-Wiener Diversity Index measures the rarity and commonness of species in a habitat. The calculated values for different habitats are given in Table 3.

**Simpsons diversity index of earthworms at different habitats:** In ecology, Simpson's Diversity Index is often used to quantify the biodiversity of a habitat. It takes into account the number of species present, as well as the abundance of each species. The calculated values for different habitats are given in Table 4.

**Margalef index of earthworms at different habitats**
Though Margalef index suffers from a dependence between species diversity and number of organisms sampled, it still remains a widely used index of diversity emphasizing species richness. The calculated values for different habitats are given in Table 5.

**Table 4.**

| Index | Bamboo | Keora | Conifer | Flower garden | GBT |
|---|---|---|---|---|---|
| Simpsons Diversity (D) | 0.42 | 0.403 | 0.335 | 0.27 | 0.559 |
| Simpsons Diversity (1/D) | 2.382 | 2.481 | 2.985 | 3.701 | 1.79 |

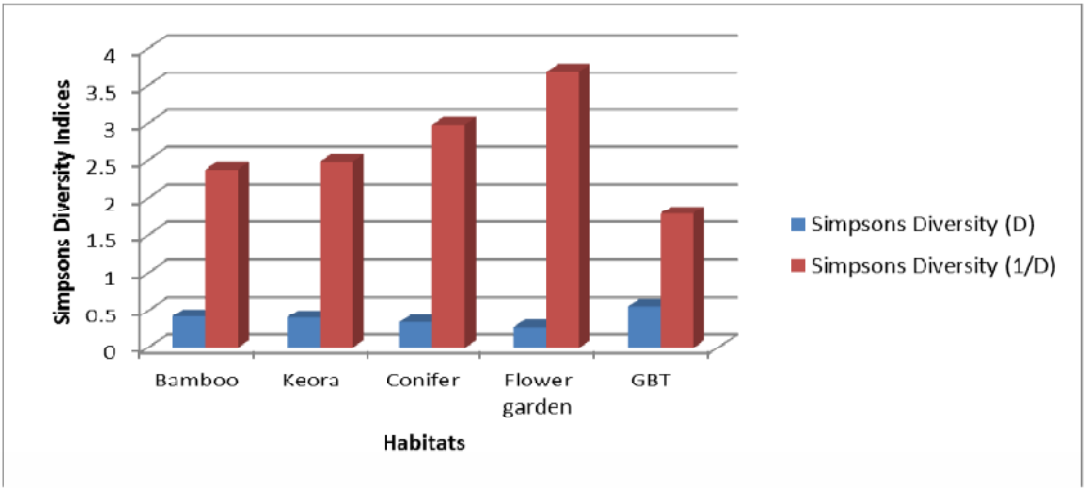



**Fig. 2.** Simpson diversity index of earthworms at different habitats.

**Table 5.**

| Index | Bamboo | Keora | Conifer | Flower garden | GBT |
|---|---|---|---|---|---|
| Margalef M Base 10. | 4.888 | 4.65 | 5.272 | 4.921 | 4.75 |

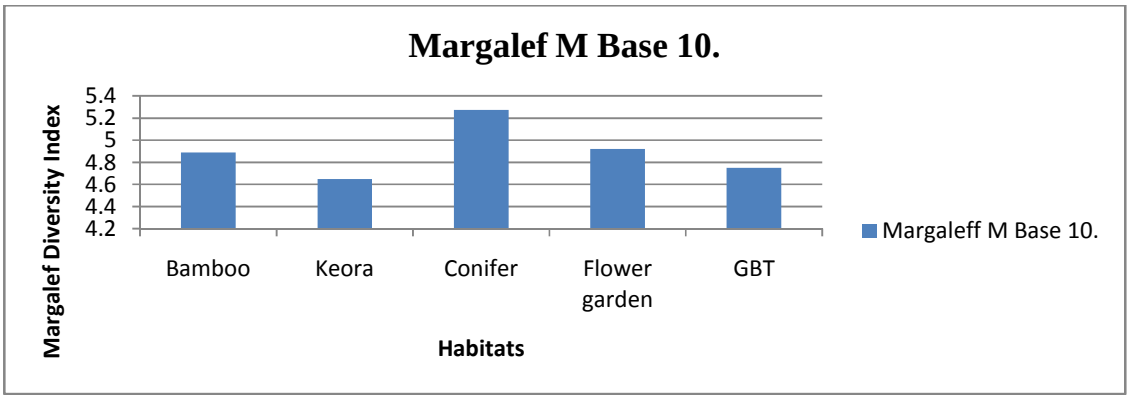



**Fig. 3.** Margalef index of earthworms at different habitats.

**Shannon evenness index of earthworms at different habitats:** Ecologists call the number of species in an area its richness, and the relative abundance of species its evenness. They are both measures of diversity. Value of evenness (J') is the relative abundance with which each species are represented in a habitat. The calculated values for different habitats are given in Table 6.

**Table 6.**

| Index | Bamboo | Keora | Conifer | Flower garden | GBT |
|---|---|---|---|---|---|
| Shannon J' | 0.629 | 0.655 | 0.729 | 0.707 | 0.49 |

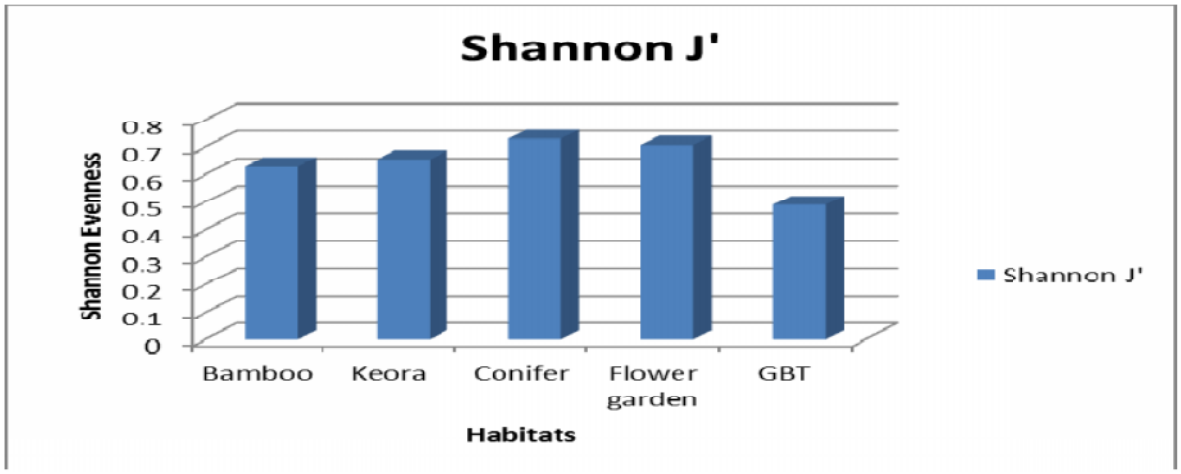



**Fig. 4.** Shannon Evenness index of earthworms at different habitats in IBG.

**Berger- Parker Dominance of earthworms at different habitats:** Berger–Parker's dominance index clarified the dominance of specific species the values of which are tabulated in Table 7.

**Table 7.**

| Index | Bamboo | Keora | Conifer | Flower garden | GBT |
|---|---|---|---|---|---|
| Berger-Parker Dominance (d) | 0.618 | 0.591 | 0.484 | 0.459 | 0.734 |
| Berger-Parker Index (1/d) | 1.618 | 1.693 | 2.068 | 2.177 | 1.362 |
| Berger-Parker Dominance (d%) | 61.798 | 59.052 | 48.361 | 45.93 | 73.43 |

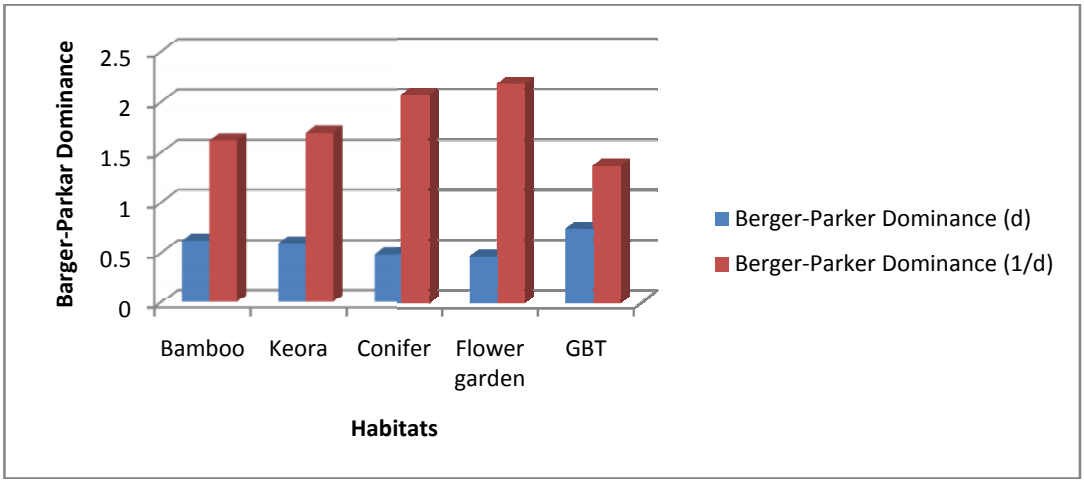
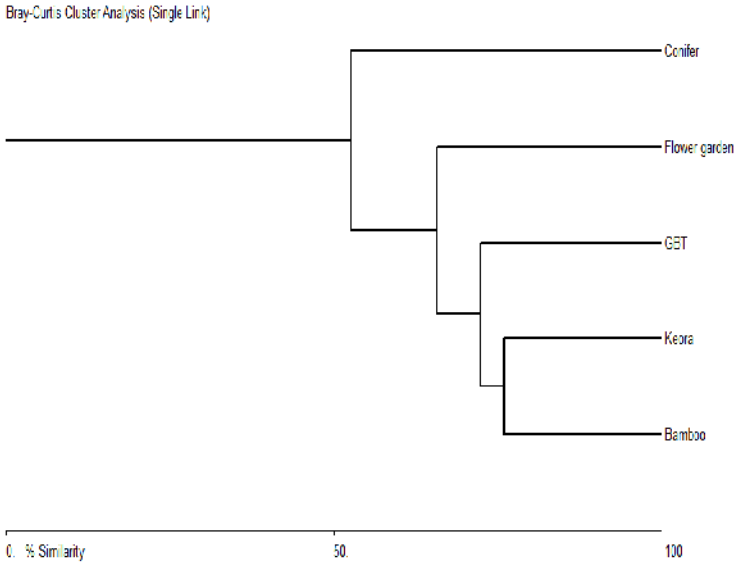



**Fig. 5.** Berger–Parker's dominance index of earthworms at different habitats in IBG.

The reciprocal of the index, 1/d, is often used, so that an increase in the value of the index accompanies an increase in diversity and a reduction in dominance. We plot the dominance index d.

**Species Similarity Index (Bray-Curtis Cluster Analysis**): The habitat similarity of earthworm species of Indian Botanic Garden were compared using Bray-Curtis Cluster Analysis index. Average faunal resemblance of earthworm species between keora and bamboo was highest (approx. 75%) followed by GBT (approx.70%) and flower garden (approx.60%) respectively. Less similarity found in conifer habitat (approx. 50%).




## DISCUSSION

The entire study calculating Species Diversity indices, Evenness, Dominance index and Taxa richness of earthworms at different habitats gives the idea of diversity of earthworms in this garden. Following is the summated values of indices including Taxa Richness.

**Table 8.**

| Habitats | Shannon H' | Simpsons Diversity (1/D) | Margalef M Base 10. | Shannon J' | Berger-Parker Dominance (d) | Taxa Richness |
|---|---|---|---|---|---|---|
| Bamboo | 0.532 | 2.382 | 4.888 | 0.629 | 0.618 | 7 |
| Keora | 0.51 | 2.481 | 4.65 | 0.655 | 0.591 | 6 |
| Conifer | 0.567 | 2.985 | 5.272 | 0.729 | 0.484 | 6 |
| Flower garden | 0.707 | 3.701 | 4.921 | 0.707 | 0.459 | 10 |
| GBT | 0.414 | 1.79 | 4.75 | 0.49 | 0.734 | 7 |

Analysis of data revealed that maximum species diversity in terms of Shannon-Wiener index and Simpsons index were found in flower garden (H´= 0.707 and 1/D = 3.701),while minimum diversity at GBT (H´ = 0.414 and 1/D = 1.79). Higher values of these indices indicate greater species diversity and thus less diversity from lower values, hence it showed higher species diversity at flower garden. Diversity index varied from 0 to 1 gives the probability that two individuals drawn from a population belong to the same species. In IBG, the species richness of all the habitat types ranged from 6 to 10 species. Edwards and Bohlen (1996) stated that earthworm diversity ranged from 1 to 15 species, while most earthworm communities contained around 3-6 species. Singh (1997) reported the occurrence of 7 to 11 species from cultivated, non-cultivated, grassland, garden and sewage soils. Fragoso *et al*. (1999) suggest that the species number in a given earthworm community, which is the easiest measure of species diversity, range from 3-17 in tropical and temperate ecosystems.

In tropical rainforests that contained generally 4 to 14 species. In this respect, habitats of IBG, with earthworm communities having 6 to 10 species, exhibit the similar diversity. Species richness, i.e. the number of different species represented in the habitat, is recorded maximum at flower garden (R = 0.767) while minimum at Keora (R = 0.394). Higher values of species richness at flower garden showed abundant food and suitable edaphic factors compared to other sites. In subtropical and tropical regions there are wider variation in species rather than species richness (Kale and Seenappa, 1997).

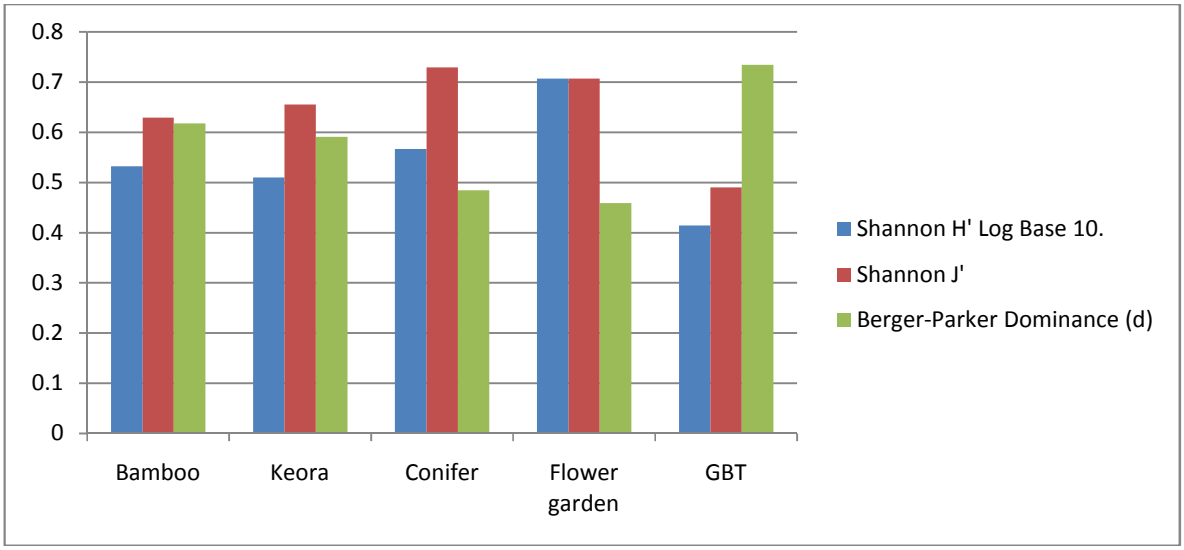



**Fig. 6.** Comparison of diversity, evenness and dominance of earthworms at different habitats.

Value of evenness (J') is the relative abundance with which each species are represented in a habitat. Here we found higher J' at Conifer habitat (J' = 0.729) while lower at GBT site (J' = 0.49). The species dominance in terms of Berger-Parker Dominance (d) were found maximum at GBT (d = 0.734) and minimum at flower garden (d= 0.459). Dominance is inversely proportional with diversity. The dominance expressing the proportion of the total example is due to the dominant species. Margalef's index shows highest at Conifer habitat (M = 0.729) and lowest at Keora (M = 4.65).

## CONCLUSIONS

The factors that influence the diversity of earthworm community at a given locality, apart from the type of soil, climate and the available organic resources, are the land use pattern and disturbance (Edwards & Bohlen 1996). Vegetation maintains soil moisture and soil living organism (Widyastuti, 2004). Poor vegetation cover and lack of plant litter in the soil surface tend to reduce the productive habitats. The more productive habitats can support more species (Pianka, 1974). The entire observation clearly indicates the richness of earthworm diversity in the present study site of Indian Botanic Garden, Howrah, Kolkata.

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