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RESEARCH ARTICLE **Open Access**

Diversity of ants species in different habitat mosaics of Acharya Jagadish Chandra Bose Indian Botanical Garden (Howrah, West Bengal, India)

Acharya Jagadish Chandra Bose Hindistan Botanik Bahçesi'nin (Howrah, Batı Bengal, Hindistan) farklı yaşam alanı mozaiklerinde karınca türlerinin çeşitliliği

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ABSTRACT

Ants (Hymenoptera, Formicidae) occupy a wide range of ecological niches and exploit various food resources either as herbivores or as predators or scavengers. This study establishes the diversity of ants in an ex-situ conservation site dedicated for plants known as Indian Botanical garden situated amidst a congested city. It also documents the relation of ant community structure with different habitat mosaics present within this protected area. For this study pit fall trap was used as collection method and amalgamated within quadrat sampling (total 16 quadrats and each quadrat contains 9 pit fall traps placed uniformly) distributed in four different habitats and repeated in two consecutive months. All the specimens were collected, preserved and identified meticulously. Total 27 species of ants from 19 genera and 6 subfamilies are documented from the whole study area. This study also reflects differences in diversity among the habitats. Among different habitats present in the Indian Botanic Garden, 'Garden-Nurseries' (Shannon_H =2.214 and Simpson_1-D=0.8333) and 'Wild Bushes and Tree groves' (Shannon_H =2.105 and Simpson_1-D=0.8182) are two most diverse habitats and 'Open scrubland with grasses' is the most dominant one (Dominance_D = 0.4354, Berger-Parker = 0.6512, Shannon_H =1.521 and Simpson_1-D=0.5646). This study clearly gives an idea about the community structure of the ants and reflects its relation with the habitats in a man-made ex-situ conservation site which establish the stability and conditions of this ecosystem.

ÖZ

Karıncalar (Hymenoptera, Formicidae) çok çeşitli ekolojik nişlere sahiptir ve otçul ya da yırtıcı ya da temizleyici olarak çeşitli gıda kaynaklarından yararlanır. Bu çalışma, sıkışık bir şehrin ortasında yer alan Hint Botanik bahçesi olarak bilinen bitkiler için ayrılmış ex-situ bir koruma alanındaki karınca çeşitliliğini ortaya koymaktadır. Ayrıca, çalışma karınca topluluğu yapısının bu korunan alanda bulunan farklı habitat mozaikleriyle ilişkisini belgelemektedir. Bu çalışma için toplama yöntemi olarak çukur düşme tuzağı kullanılmıştır ve dört farklı habitatta dağıtılan ve birbirini takip eden iki ay içinde tekrarlanan kuadrat örneklemesi (toplam 16 kuadrat ve her kuadrat muntazam yerleştirilmiş 9 çukur düşme tuzağı içermektedir) içinde birleştirilmiştir. Tüm örnekler toplanmış, korunmuş ve titizlikle tanımlanmıştır. Tüm çalışma alanından 19 cins ve 6 alt aileden toplam 27 karınca türü belgelenmiştir. Bu çalışma aynı zamanda habitatlar arasındaki çeşitlilik farklılıklarını da yansıtmaktadır. Hint Botanik Bahçesi'nde bulunan farklı habitatlar arasında 'Bahçe-Fidanlık' (Shannon_H = 2.214 ve Simpson_1-D = 0.8333) ve 'Yabani Çalılar ve Ağaç Bahçeleri' (Shannon_H = 2.105 ve Simpson_1-D = 0.8182) en çeşitli iki habitattır ve 'otlu açık çalılık alanı' en baskın olanıdır (Dominance_D = 0.4354, Berger-Parker = 0.6512, Shannon_H = 1.521 ve Simpson_1-D = 0.5646). Bu çalışma, karıncaların toplum yapısı hakkında açıkça bir fikir vermektedir ve bu ekosistemin istikrarını ve koşullarını oluşturan insan yapımı bir ex-situ koruma alanındaki habitatlarla ilişkisini yansıtmaktadır.

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1. INTRODUCTION

Ants (Hymenoptera, Formicidae) are one of the most diverse, abundant and ecologically significant organisms on earth (Holldobler & Wilson, 1990; Grimaldi & Engel, 2005). Mostly, they have the highest species richness in the Neotropics but patterns of ant diversity and distributions are still not very well defined (Ryder Wilkie et al., 2010). Competitions in biological communities giving rise to "assembly rules" that forces the species to co-exist in their respective habitats (Yusah et al., 2018). Ant communities in tropical countries often display a particular pattern of assemblage known as "ant mosaic" with mutually exclusive niches (Fayle et al., 2013).

Understanding actual ecological conditions of a particular habitat or an ecosystem with diverse biotic and abiotic components are very intricate and herculean task, because no single group of organisms can indicate the wholesome status of a particular habitat or biome. The most practical solution of this problem is to survey those groups of organisms, which are ecologically significant, comparatively easy to collect as specimens and at least certain amount of taxonomic and other related knowledge base is available (Fisher et al., 2011; Vink et al., 2012). Ants, more precisely ground-dwelling ants are the most suitable components for the above-mentioned approach. Ants are very important group of species among the whole range of biodiversity found all over the world. High diversity and capability to adapt in various kinds of habitats show its unique evolutionary significance. It serves important ecological functioning including interactions with other organisms at every trophic level and apart from that, it also acts as an important ecological indicator (Anderson, 1993; Lindenmayer et al., 1999). In this context, ants play as major functional groups that can provide a widespread and predictive understanding of community responses to ecological disturbance (Hoffman & Andersen, 2003; Lassau & Hochuli, 2004).

Plenty of works had been done in different ecosystems ranging from the wild (like forests, mountain etc.) to human altered habitats (like agricultural land, orchards etc.) to understand the ecological scenario of those places but very little work have been found in such large sized ex-situ conservation site comprising various habitat mosaics like Acharya Jagadish Chandra Bose Indian Botanical Garden (Evans et al., 2011; Buczkowski & Richmond, 2012; Santos, 2016; Angulo et al., 2016). At this time of rapid urbanization and habitat loss, it is important to understand the ecological distribution of ants in these kinds of big human altered gardens which actually are working as an oasis amidst a densely populated city.

Acharya Jagadish Chandra Bose Indian Botanical Garden is situated at Howrah district of West Bengal (Figure 1) in the bank of river Bhagirathi, the West Bengal segment of river Ganges and globally famous for its hundreds of years-old Great Banyan tree. It comprises diverse tree species collected from different parts of the world and along with its artificial manmade environment a sufficient portion of garden area also consist of several fragmented wild habitat patches. Thus, this study was designed aiming to find out the community assemblage of different ant species documented from the entire study area and to investigate its relational pattern with different habitat mosaics present here.

2. MATERIALS AND METHODS

2.1. Study area

Indian Botanical Garden (also known as Acharya Jagadish Chandra Bose Indian Botanical Garden) (22°33'23.31" N; 88°17'7.95" E) is an artificially built ex-situ conservation site managed by the Botanical Survey of India (a Government of India Organization) enclosed with diverse tree species collected from different parts of the world (Mukherjee, 2012). This is the largest Botanical Garden of India with 109 ha of coverage having 24 lakes in the garden which are interconnected with underground pipes and connected with the river Bhagirathi through sluice gates for the regular inlet and outlet of water (Figure 1) (Royal Botanic Garden, Calcutta Index, 1830). The best-known landmark of the garden is The Great Banyan tree, an enormous banyan tree (*Ficus benghalensis* L.) that is renowned to have the largest canopy in the world, at more than 330 meters in circumference (Sambamurty, 2005). The gardens are also famous for their massive collection of orchids, bamboos, palms, and plants of the screw pine genus (*Pandanus*) from different parts of world. Along with these exotic and rare trees, some portions of the garden remain unmaintained and transformed into mini patches of wild trees and undergrowth. The annual mean temperature is 24.8°C; Summers are hot and humid with temperatures in the low 30's and during dry spells the maximum temperatures often exceed 40°C during May and June. Winter tends to last for only about two and a half months, with seasonal lows dipping to 9°C – 11°C between December and January. Annual rainfall and relative humidity of the area is 805 mm/year and 75% respectively.

2.2. Methodology

2.2.1. Study design

A pilot survey was conducted prior to core sampling effort for understanding the situation of the study area and to finalize the sampling techniques. The foremost reason behind this is to know the habitat mosaics (vegetation patterns and real-world structural constituents), entomological diversity and anthropogenic interferences of the whole garden (Wright et al., 2004). After pilot survey; the study area was broadly divided into four different sub-habitats (Table 1) and placed accordingly on an actual scale map provided by Botanical Survey of India.

Sub-habitat type	Description
Wild Bushes and Tree Groves	Wild vegetation like bushes and thickets, one or more trees with dense undergrowth in a small area, thorny scrub jungles, patch of bamboo groves
Open scrubland with grasses	Open land covered by small grass with scattered herbs and shrubs. These areas are regularly maintained by the BSI authorities.
Wetland Banks	Banks of these wetlands are often covered by different kind of vegetation and act as 'Ecotone' between both terrestrial and aquatic community.
Garden-Nurseries	These areas constitute of different kinds of ornamental plants regularly maintained using different fertilizers and pesticides

Table 1. Description of the sub-habitat types of study area.

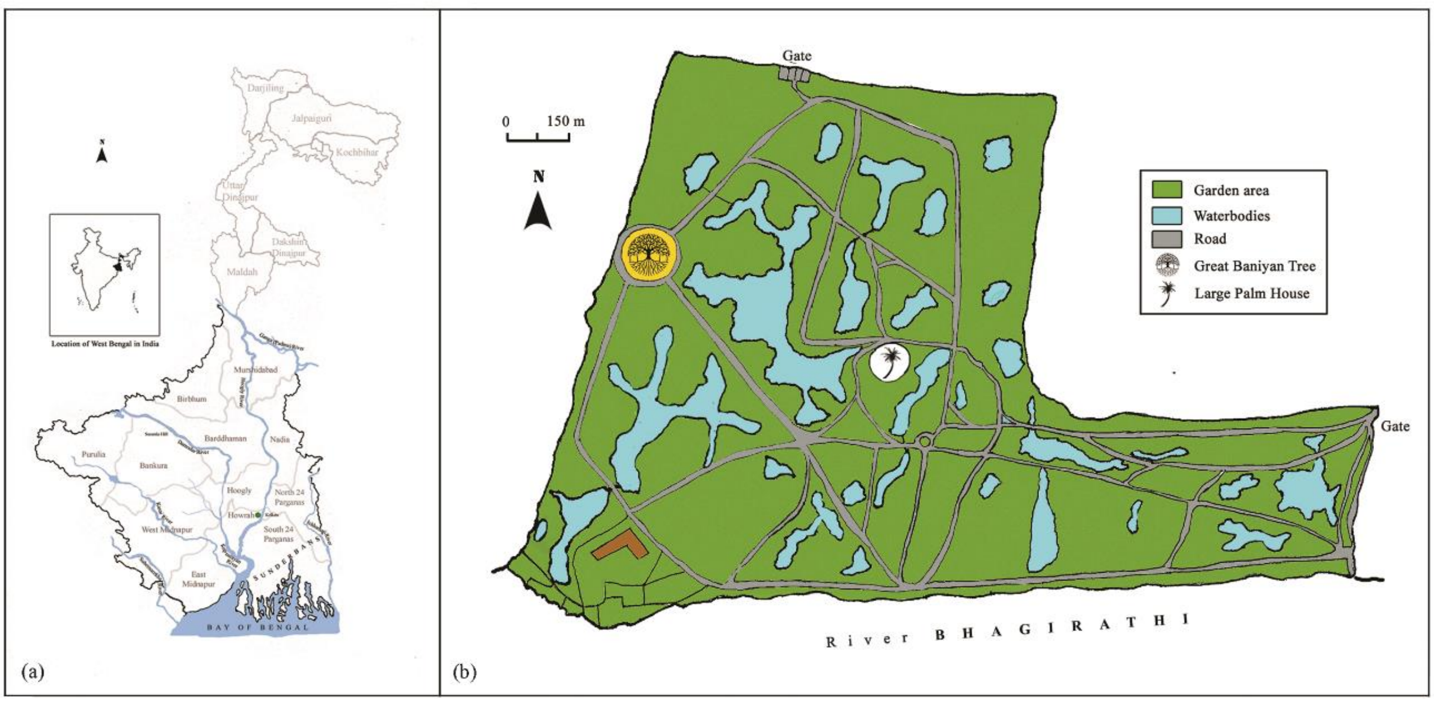

Figure 1. (a) Location of the Indian Botanical Garden in West Bengal and India. (b) Outline map of habitat coverage of Indian Botanical Garden.

After a thorough literature review and pilot survey, 'Pit fall' sampling technique was found to be most suitable for this work and implemented as main specimen collection technique for further in-depth study (Robertson et al., 1999; Wang et al., 2001; Ward et al., 2001; Larsen et al., 2003; Holland & Reynolds, 2005; King & Porter, 2005; Sutherland, 2006). Pits were created using disposable glasses (diameter 40mm, height 85mm) with half-filled detergent water and dug into soil. Following that its edges were flush with soil and covered with leaf litters to hide these traps from ants' trail. For in-depth sampling, two quadrats (size 10mx10m) were established in each habitat and each quadrat was subdivided into 16 grids (size 2.5m x 2.5m), Within those 16 grids 9 pit falls were placed in uniform distribution for overnight period. While placing the pit fall traps, all the habitat details (Height of tree, shrub and herb; Number of trees present; Number of shrubs present; Ground litter depth and surface coverage; Surface coverage of grass, Shrubs and trees (%); Canopy cover at the center of the quadrat) were noted meticulously. Each pit fall was kept for 24 hours, ants were collected meticulously, preserved in separate vials with 70% ethyl alcohol and the entire sampling process was repeated twice (March and April 2018) in each habitat. After collection all the specimen were brought into laboratory, mounted precisely and identified up to species level (Bingham, 1903; Bolton, 1994; Bolton et al., 2007). A few representative specimens from each species were stored in a cool dry collection case for reference of future ant identification. All the specimens including wet and pinned ones were kept in the National Zoological Collections of Zoological Survey of India.

2.2.2. Data analysis

Following the collection of samples detailed analysis had been done based on all the habitat variables and ant species using MS Excel 2007, BioDiversity Professional Version 2 and PAST 3.2 software packages. Primarily species richness (Taxa_S) and its relative abundance (p_i) were calculated in the whole study area as well as within each habitat type followed by different diversity indices like Shannon diversity index (Shannon_H), Simpson's index (Simpson_1-D), dominance (Dominance_D), evenness (Evenness_e^H/S) etc. Rarefaction curve was drawn to estimate the number of ant species found in the study area and to standardize the sampling methods. Rank abundance curve of ant species in whole study area and in each habitat was calculated to understand the distribution of each species. SHE analysis [S (species richness), H (Shannon Diversity Index) and E (evenness) in the samples] was done to understand the relation between species richness and its diversity, Correlation co efficient (R) between habitat variables and species diversity of species was also calculated.

3. RESULTS & DISCUSSIONS

3.1. Community assemblage and diversity of species

A total of 530 individuals were collected during the study, representing 6 subfamilies, 19 genera and 27 ant species (Table 2). The richest subfamily was Formicinae, containing 11 species and 7 genera, followed by Ponerinae (7 species, 4 genera), Myrmicinae (5 species, 5 genera). Subfamily Dolichoderinae and Dorylinae contain 1 species of respective genus each while subfamily Pseudomyrmicinae contains 2 species of 1 genus. The most species rich genus was *Camponotus* represented by 4 species, followed by *Leptogenys*, *Bothroponera*, *Polyrhachis*, *Tetraponera* and *Diacamma* each genera containing 2 species. Among all the species *Pheidole* sp. was the most abundant one (40.94%) followed by *Carebara affinis* (13.2%), *Camponotus compressus* (6.42%), *Diacamma indicum* (6.42%) (Figure 2). A rarefaction curve (Figure 3) reflects that the sampling was adequate, curve reached asymptote and shows almost every species found in the study area were estimated from the sample.

Abundance rank of all the species and their distribution pattern within the entire study area is reflected from Figure 4 and Figure 5. Figure 4 reveals the rank abundance of the total area which is mostly dominated by single species (*Pheidole* sp., p_i= 0.41) and apart from that other species present in the community are more or less even. The abundance rank of species (Figure 5) in different habitats and clearly explains the distribution of species is more or less even (except very little dominance of certain species) in all the communities except 'Open scrubland with grasses'

The species richness of ants (Taxa_S) is more or less similar in all the habitat types (ranging from 15 to 18; Table 3) studied in the botanical garden area but there are considerable differences in species abundance between the habitats (Figure 6). Maximum numbers of individuals were collected from the habitat named 'Open scrubland with grasses' (215) and it is extremely dominated by a single species (*Pheidole* sp.). It also raises the individual density of ants in a particular habitat type in compare to others (Figure 5).

The diversity of ant species in Indian Botanic Garden is showing that its community is fairly stable and healthy (Table 3). The diversity indices of the whole garden area (Shannon_H =2.219 and Simpson_1-D=0.7963) is relatively moderate which reflects an evidence of its stable nature. Among different habitats present in the Indian Botanic Garden, 'Garden-Nurseries' (Shannon_H =2.214 and Simpson_1-D=0.8333) and 'Wild Bushes and Tree groves' (Shannon_H =2.105 and Simpson_1-D=0.8182) are two most diverse habitats and 'Open scrubland with grasses' is the most dominant one and eventually become the least diverse one (Dominance_D=0.4354, Berger-Parker=0.6512, Shannon_H=1.521 and Simpson_1-D=0.5646) among the four habitat types. On the other side the habitat called 'Wetland Banks' possess an ant community where species are distributed more evenly (Evenness_e^H/S=5.279, Equitability_J=0.7641) (Table 3, Figure 7).

3.2. Habitat preference of different ant species

Out of 27 species, only 7 shared varies range of habitat niche (25.92% of all the species) as all of them found in all 4 habitat types (Figure 8). 8 species (29.62%) were restricted to only one habitat and 7 were restricted to two habitats (25.92%). Among these 8 species (who were restricted to a single habitat) 5 were exclusively found in a habitat named 'Wild Bushes and tree groves' (18.51% of all the species). Two species are exclusively found in 'Open scrubland with grasses' and 1 in 'Garden-Nurseries'. From figure 8 it is clearly understandable that most of the ant species prefer to live in their own niche and show very minimum overlap in habitat preferences. Habitat called 'Garden-Nurseries' comprises maximum number of species (Taxa_S=18; Table 2) as it preferred by the most of the ants.

SHE analysis examines the relationship between S (species richness or Taxa_S), H (Shannon-Wiener Diversity Index) and E (evenness as measured using the Shannon-Wiener evenness index or Evenness_e^H/S) in the samples. It is therefore an approach to look at the contribution of species number and equitability to changes in diversity. Figure 9 shows the diversity (H) and evenness (LnE) vary according to the sample (habitats) but the species richness and ratio between species richness and evenness (LnE/LnS) shows a steady pattern in different habitats. This analysis reflects the stability of the ant community in the entire botanical garden irrespective of habitat variations. Different habitats may support different kinds of species but SHE analysis shows that habitat mosaics cumulatively help the ant community all together to be stable and healthy.

Apart from the habitat clusters (discussed previously), it is also important to understand the other habitat parameters that have significant impacts on the composition and diversity of ant species. Hence correlation coefficient (r) between habitat variables (like height of tree, shrub and herb, no. of trees and shrubs, ground litter depth and its surface coverage, canopy cover etc.) and different parameters of diversity (LnS, Dominance_D, Simpson_1-D, Shannon_H, Evenness_e^H/S) was calculated from the samples (Figure 10). The result of this study clearly depicts a strong and positive correlation between height of the vegetation (both tree and shrub) and diversity of the ant species (Simpson_1-D and Evenness_e^H/S). Apart from that ground litter also plays a crucial role to enrich the species diversity. Litter increases the soil organic matters and that help to attract different ant species. That's why places with more ground litter hold diverse kinds of species. Whereas open habitats covered with grasses shows mono-specific vegetation and hence it attracts very few species with high abundance. As result of that, it shows a positive correlation with species dominance and negative correlation with diversity. Places covered with canopy give shades to the ground and maintain the temperature and humidity of that particular area that also attracts diverse species of ants.

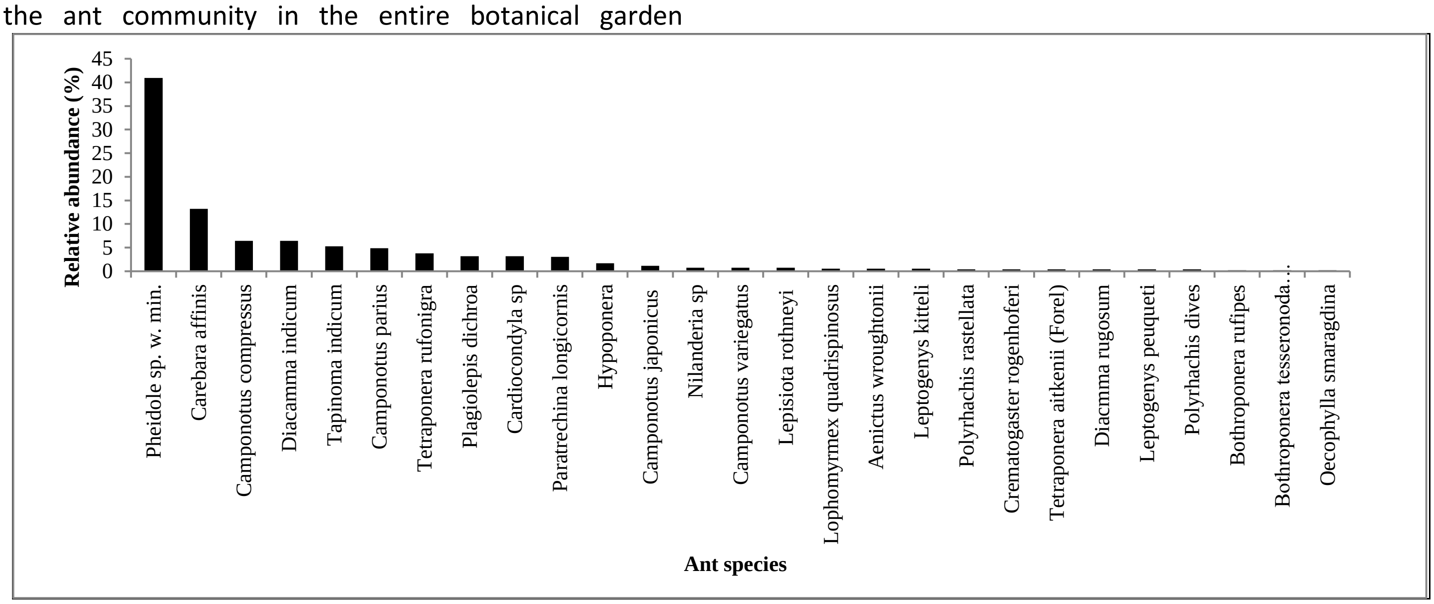

Figure 2. Relative abundance of ant species in Indian Botanical Garden.

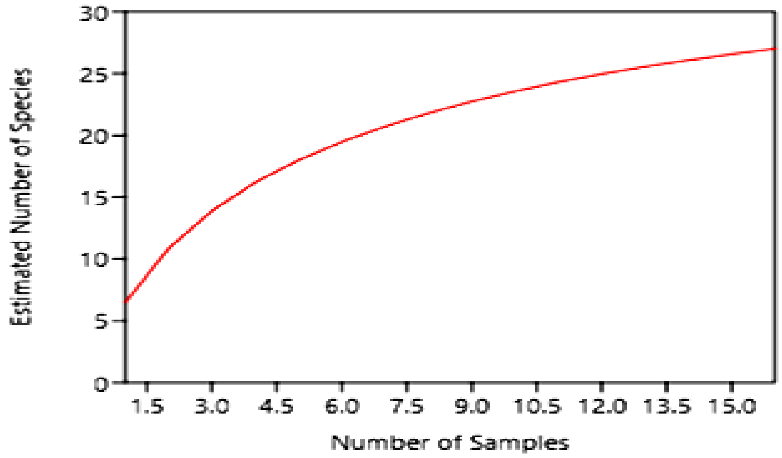

Figure 3. Rarefaction curves of estimated number of ant species collected in pitfall traps for all habitats in the Indian Botanical Garden.

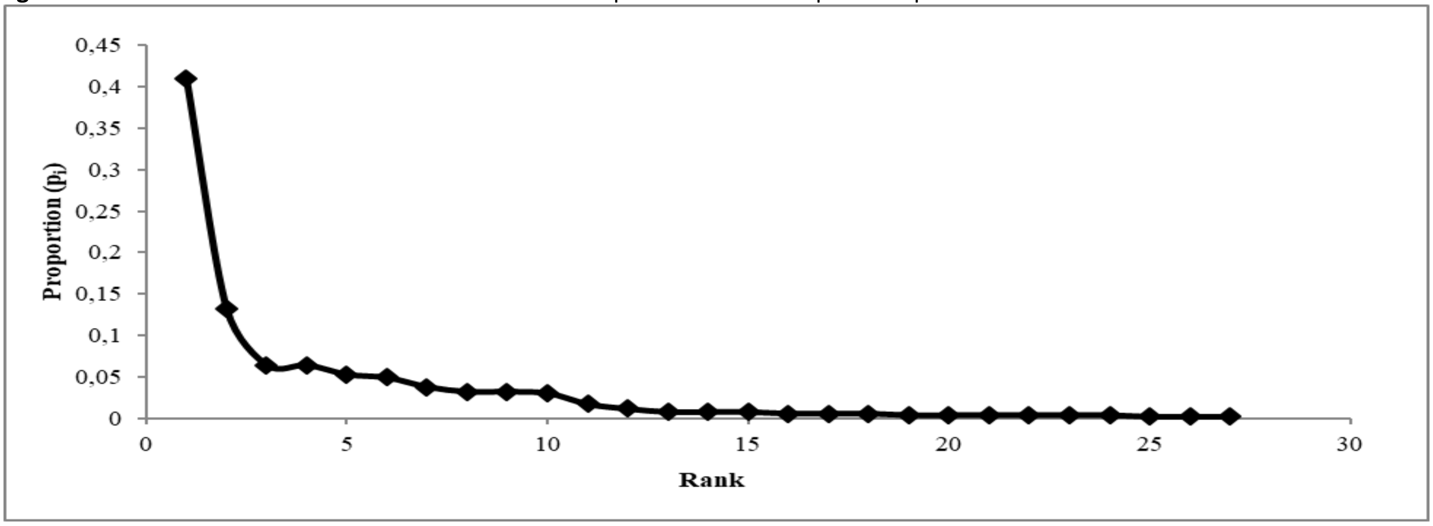

Figure 4: Rank abundance curve of ant species in Indian Botanical Garden.

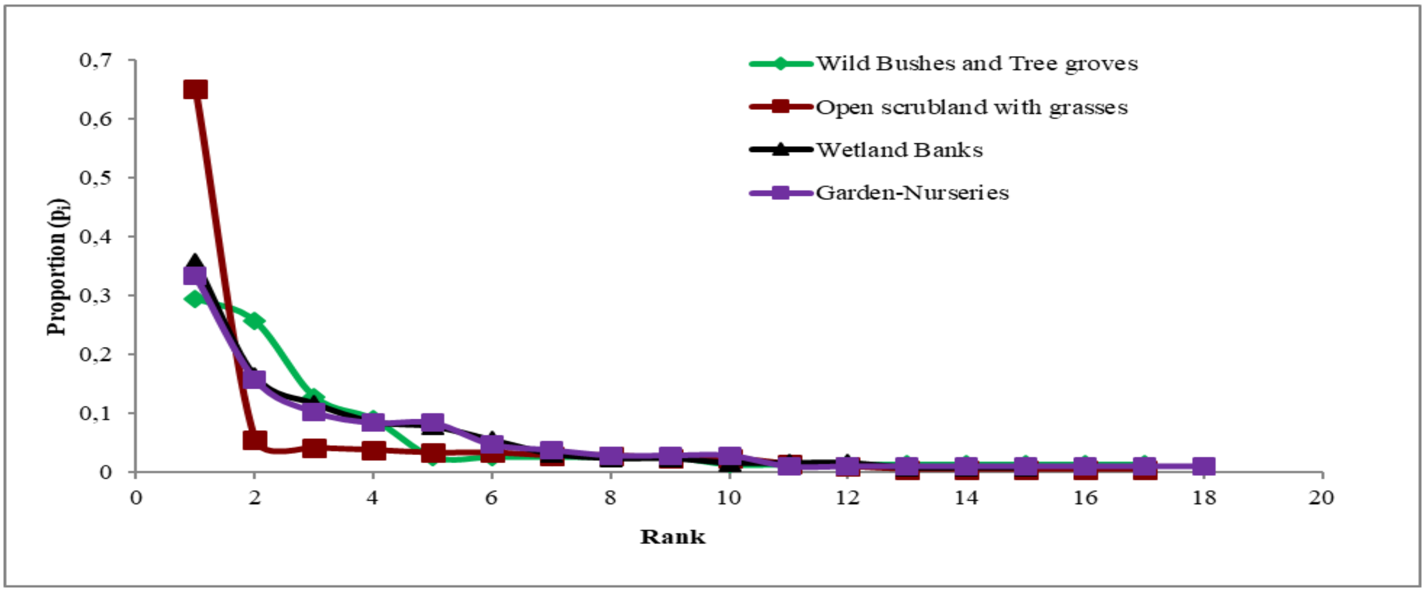

Figure 5. Rank abundance curve of ant species in Indian Botanical Garden in different habitats.

Table 2. List of Ant species found in Indian Botanic Garden.

Species name		Genera	Subfamily
1.	*Tapinoma indicum*	*Tapinoma*	Dolichoderinae
2.	*Aenictus wroughtonii*	*Aenictus*	Dorylinae
3.	*Camponotus compressus*	*Camponotus*	Formicinae
4.	*Camponotus japonicus*	*Camponotus*	Formicinae
5.	*Camponotus parius*	*Camponotus*	Formicinae
6.	*Camponotus variegatus*	*Camponotus*	Formicinae
7.	*Lepisiota rothneyi*	*Lepisiota*	Formicinae
8.	*Nylanderia* sp.	*Nylanderia*	Formicinae
9.	*Oecophylla smaragdina*	*Oecophylla*	Formicinae
10.	*Paratrechina longicornis*	*Paratrechina*	Formicinae
11.	*Plagiolepis dichroa*	*Plagiolepis*	Formicinae
12.	*Polyrhachis dives*	*Polyrhachis*	Formicinae
13.	*Polyrhachis rastellata*	*Polyrhachis*	Formicinae
14.	*Cardiocondyla* sp.	*Cardiocondyla*	Myrmicinae
15.	*Carebara affinis*	*Carebara*	Myrmicinae
16.	*Crematogaster rogenhoferi*	*Crematogaster*	Myrmicinae
17.	*Lophomyrmex quadrispinosus*	*Lophomyrmex*	Myrmicinae
18.	*Pheidole* sp. w. min.	*Pheidole*	Myrmicinae
19.	*Bothroponera rufipes*	*Bothroponera*	Ponerinae
20.	*Bothroponera tesseronoda (Mayr)*	*Bothroponera*	Ponerinae
21.	*Diacamma indicum*	*Diacamma*	Ponerinae
22.	*Diacamma rugosum*	*Diacamma*	Ponerinae
23.	*Hypoponera* sp.	*Hypoponera*	Ponerinae
24.	*Leptogenys kitteli*	*Leptogenys*	Ponerinae
25.	*Leptogenys peuqueti*	*Leptogenys*	Ponerinae
26.	*Tetraponera aitkenii (Forel)*	*Tetraponera*	Pseudomyrmicinae
27.	*Tetraponera rufonigra*	*Tetraponera*	Pseudomyrmicinae

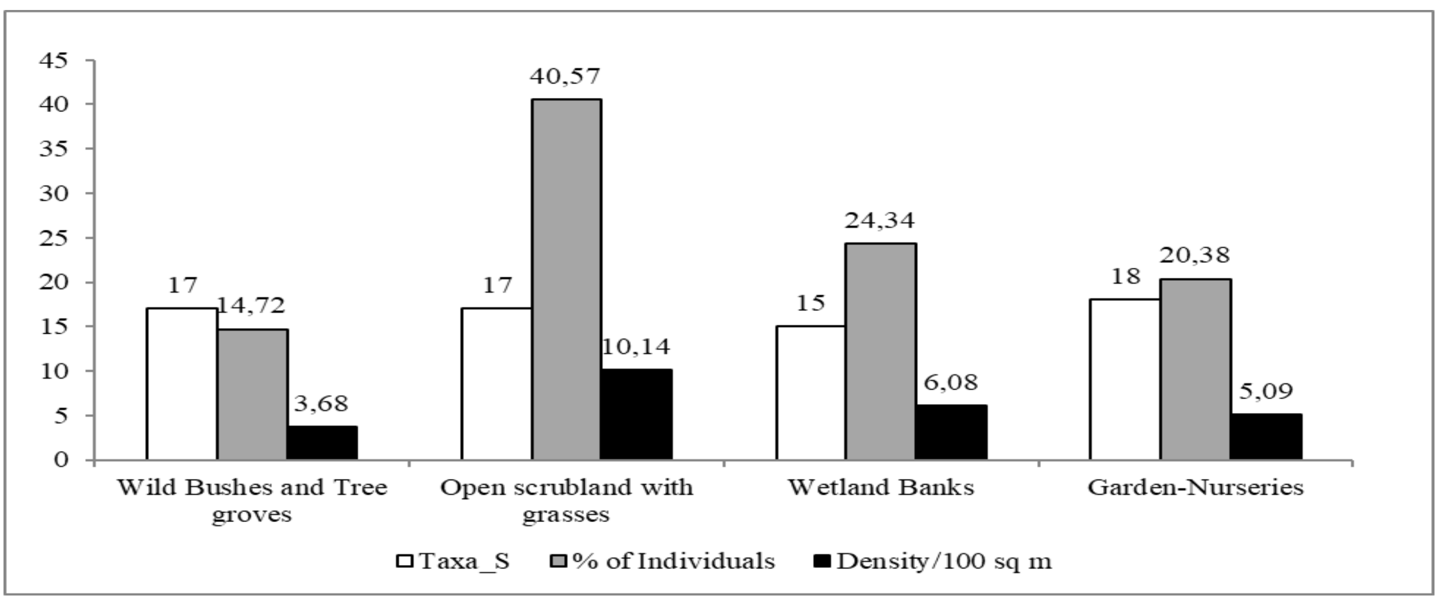

Figure 6. Habitat wise occupancy of Ant: species richness, relative abundance (%) and density (/100sq m).

Table 3. Estimation of diversity in different habitat types of Indian Botanic Garden.

	Whole Garden Area	Wild Bushes and Tree groves	Open scrubland with grasses	Wetland Banks	Garden-Nurseries
Taxa_S	27	17	17	15	18
Individuals	530	78	215	129	108
Dominance_D	0.2037	0.1818	0.4354	0.1863	0.1667
Simpson_1-D	0.7963	0.8182	0.5646	0.8137	0.8333
Shannon_H	2.219	2.105	1.521	2.069	2.214
Evenness_e^H/S	0.3406	0.4829	0.2693	0.5279	0.5084
Brillouin	2.131	1.845	1.407	1.9	1.993
Menhinick	1.173	1.925	1.159	1.321	1.732
Margalef	4.145	3.672	2.979	2.881	3.631
Equitability_J	0.6732	0.7431	0.537	0.7641	0.7659
Fisher_alpha	6.013	6.701	4.332	4.395	6.168
Berger-Parker	0.4094	0.2949	0.6512	0.3566	0.3333
Chao-1	27.43	21.67	22	15.75	46

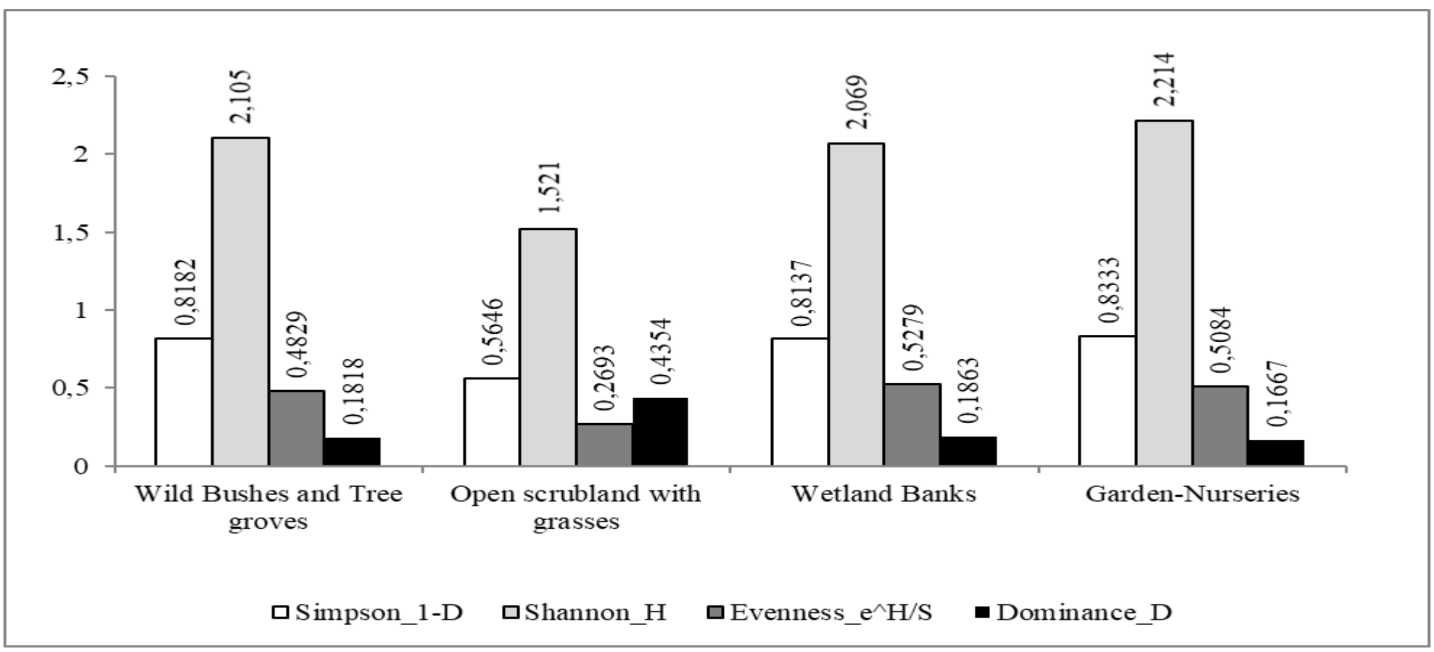

Figure 7. Diversity of Ants in different habitat types.

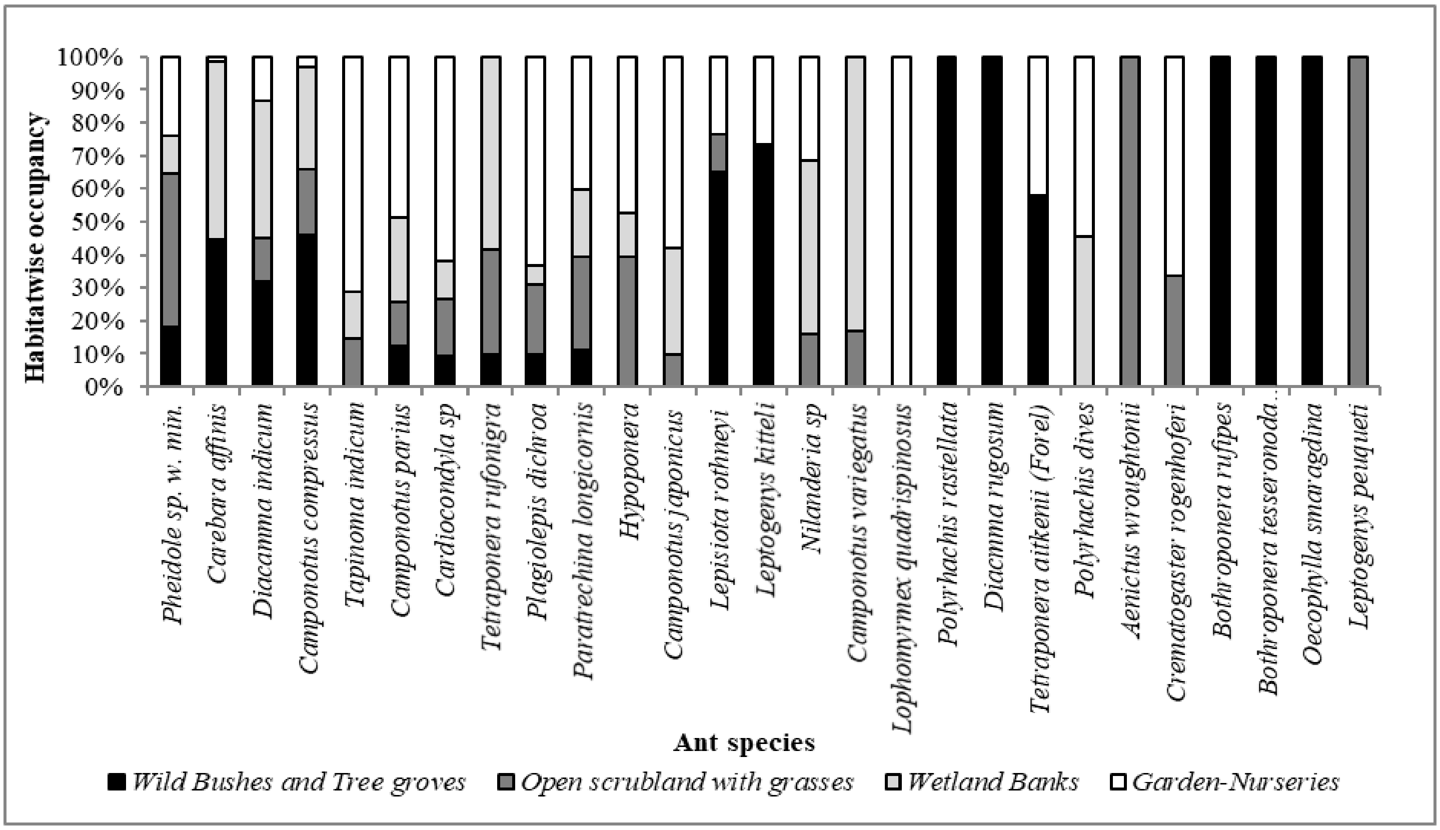

Figure 8. Habitat wise occupancy (%) of different ant species.

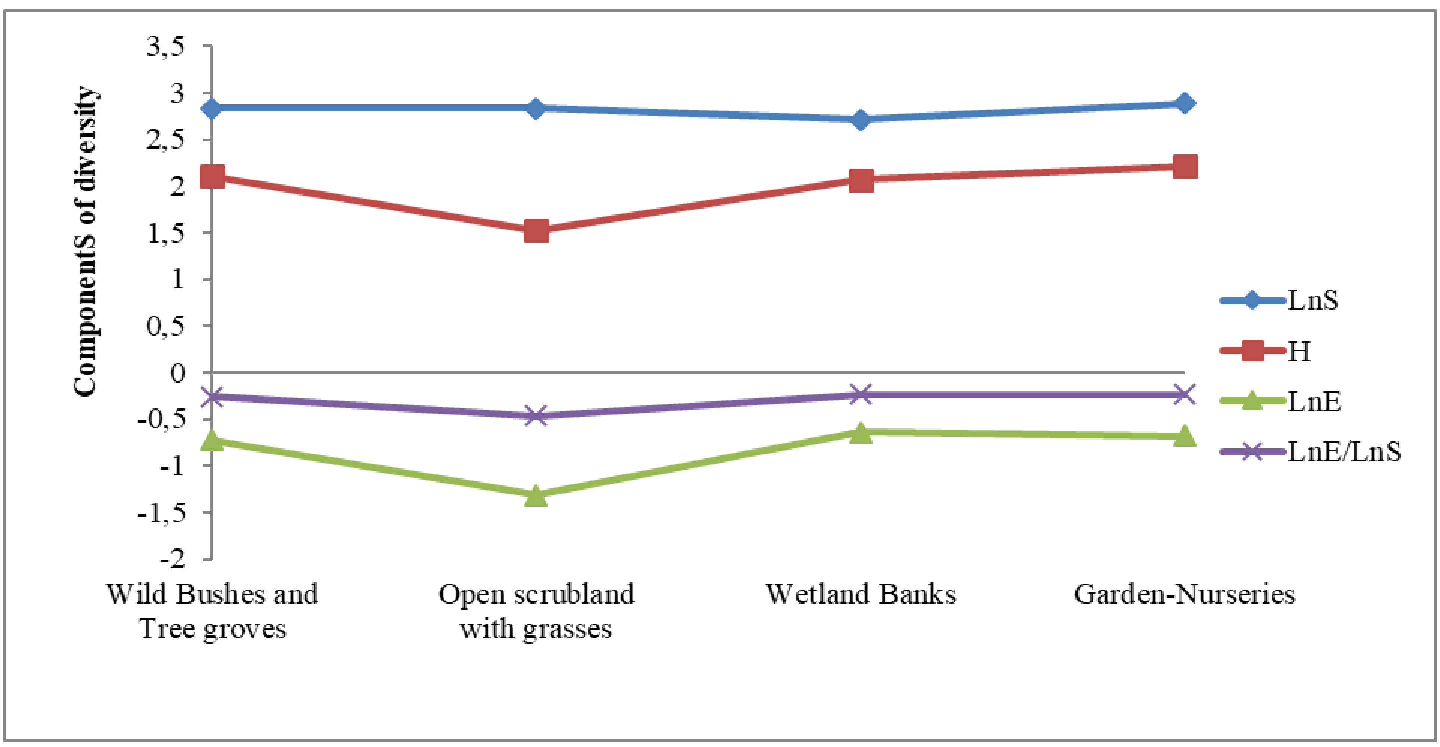

Figure 9. Representation of SHE analysis for Ant species.

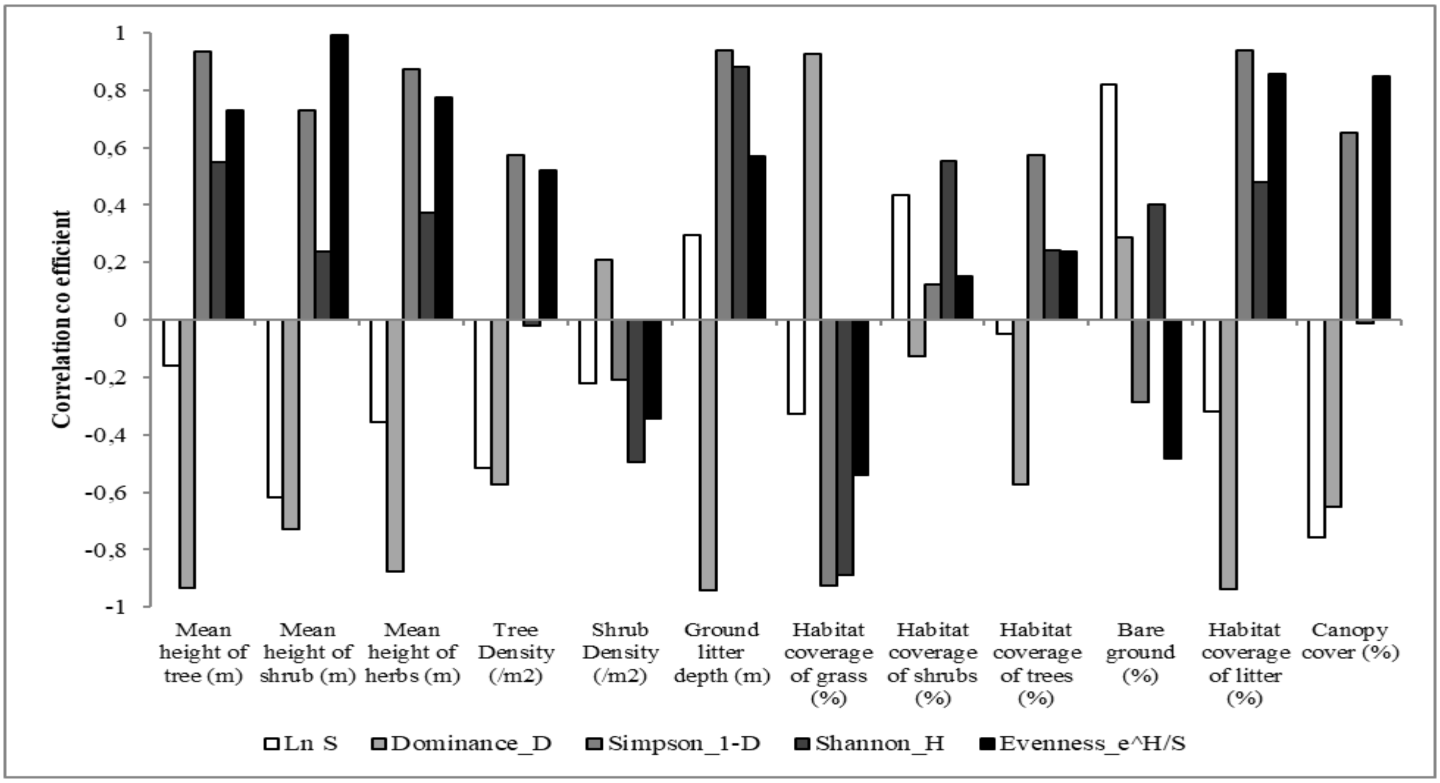

Figure 10. Correlation co efficient between habitat variables and diversity of species.

4. CONCLUSION

Among the different fauna found in the botanical garden area, ants are performing as a very important ecological component. A diverse ant community acts as an environmental indicator of that particular habitat and shows the health of that ecosystem i.e., the ecosystem is in stable state or in degraded conditions. Presence of different kinds of vegetation in the study area allows diverse species of ants to use it as their habitat niche. 27 (7.06% of the all species found in entire state) species of ants from 19 genera (29.23% of genera found in entire state) and 6 subfamilies are documented from this small study area which is good enough in compare to the number of genera (65) and species (382) found in the entire state of West Bengal (Bharti et al., 2016). Occurrence of habitat mosaic throughout the garden area not only helps to increase the assemblage of ants within each habitat types but also enhance the overall steadiness of their community structure. The range of different diversity indices (1.521-2.214) reflect the stability of the ant community within the garden area. This study moreover reflects that different habitat variables play key factors for maintaining this community so wealthy and stable. High positive correlation between different habitat variables and various diversity parameters explains the real reason behind this condition.

All the above-mentioned results clearly fulfill the aim and leads to the conclusion that botanical garden area is an important ecosystem for different ant species. Mono-specific plant growth and eutrophication in the number of wetlands may reduce the ant diversity in some parts of in the garden which should be taken care of otherwise it cannot sustain these huge diverse group of ants in this small garden area. However, regardless of these little disturbances still it can be concluded that maintaining this kind of ex-situ ecosystem amidst of urban landscape can become an oasis for ants and if managed properly it can maintain the balance of ecosystem efficiently. This study pointed out how a small garden area can play an essential ecological function in a highly disturbed ecosystem, when the habitat destruction becomes a regular phenomenon all over the world.

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