Munis Entomology & Zoology
https://www.munisentzool.org/
ISSN 1306-3022

Mun. Ent. Zool.
(January, 2021)

ROLE OF PHYSICOCHEMICAL PARAMETERS ON DIVERSITY AND ABUNDANCE OF GROUND–DWELLING, DIURNAL ANT SPECIES OF DURGAPUR GOVERNMENT COLLEGE CAMPUS, WEST BENGAL, INDIA

Anneswa Mukherjee* and Utpal Singha Roy**

* Post Graduate Department of Conservation Biology, Durgapur Government College, J. N. Avenue, Durgapur – 713214, Paschim Bardhaman, West Bengal, INDIA. ORCID ID: 0000-0002-8737-8385
** Department of Zoology, P. R. Thakur Government College, Thakurnagar – 743287, North 24 Parganas, West Bengal, INDIA. E-mail: srutpal@gmail.com, ORCID ID: 0000-0001-8683-1056

[Mukherjee, A. & Roy, U. S. 2021. Role of physicochemical parameters on diversity and abundance of ground–dwelling, diurnal ant species of Durgapur Government College Campus, West Bengal, India. Munis Entomology & Zoology, 16 (1): 366-380**]**

ABSTRACT: The present study was conducted to enlist diurnal, ground dwelling ant species from Durgapur Government College Campus, West Bengal, India. Seven different physicochemical parameters were analyzed to comment on the possible influence of these parameters on the occurrence pattern, abundance and niche breadth of ant species. Pitfall method was applied to collect 31 ant species under 18 genera and 5 subfamilies within a study span of three months (April – June). The most diverse ant subfamily recorded in the present study was Myrmicinae (47% species) followed by Formicinae (28% species) while the most diverse genus was *Camponotus* (6 species) followed by genera *Crematogaster* (4 species) and *Monomorium* (3 species). *Camponotus compressus* (Fabricius) was recorded as the most abundant ant species followed by *Monomorium pharaonis* (Linnaeus). Positive correlations were found between ant diversity and ambient relative humidity, soil moisture, soil conductivity and soil organic carbon whereas negative correlations were noted between ant diversity and ambient temperature, solar irradiance and pH. These findings were further verified with one–way ANOVA, Cluster analysis and CCA plot. *Pseudoneoponera rufipes* (Jerdon) followed by *Tetraponera rufonigra* (Jerdon) and *Camponotus compressus* occupied the maximum niche breadth reflecting their adaptability to forage in a larger area from the present study location.

KEY WORDS: Formicidae, urban insect diversity, physicochemical parameters, diversity indices, habitat selection, ant community, Hymenoptera

The global diversity of insects has been predicted to comprise approximately 5.5 million species (Stork, 2018). In the insect world, ants have been known as a diverse taxon that contribute to substantial fraction of biomass in many terrestrial communities (King et al., 2013). This huge abundance of ants ought to influence ecosystem functioning. Actually, it has been reported that they can act as ecological engineers to move and fertilize soil much like earthworms (Lyford, 1963). Moreover, they play a vital role in the food web as they may act as pray for ant eaters belonging to different animal taxon or as predators of other insects and small invertebrates apart from being scavengers. Additionally, they have been found as excellent pollinators and support in dispersal of many plant species (Lach et al., 2010). Due to their super adaptive power to occupy diverse habitats and ability to respond to stress, ants have been proposed as excellent ecological as well as environmental indicators (Majer, 2007). Accordingly, the study of distribution and abundance of ant species will enrich our knowledge about their ecological functions as well as assessment of ecosystem health and biodiversity monitoring.

The role of environmental and biogeographic factors on the assemblage pattern of ants from different parts of the globe are on record. However, considering the constant change in global climate it is imperative to continue such studies both at the larger and local scales. Mention may be made that it is next to impossible to carry out holistic account of biodiversity since, it requires enormous levels of effort and time (Lawton et al., 1998). Accordingly, emphasis has been given on rapid studies during the last few decades (Roberts, 1991), frequently focusing on individual taxa (Noss, 1990; Pearson, 1994), or by concentrating on particular habitat types (Kiester et al., 1996). Ants represent an excellent opportunity in this respect since, many species can be sampled in a shorter time because of the high abundance of workers and predefined sampling methods. Information thus obtained can provide an indication of habitat quality or conservation value as well. Diversity and distribution of ant species from India are well on record and the state West Bengal harbours the highest number of ant species (382) belonging to 65 genera (Bharati et al., 2016).

However, to the best of our knowledge no reports on the diversity of ants have been published from the Paschim Bardhaman district. Thus, the primary objective of the current study was to prepare a checklist of ground dowelling ant species from the present study location within a shorter time span. Efforts were also made to comment on the influence of physicochemical parameters on the occurrence pattern, abundance and niche breadth of diurnal ant species.

MATERIALS AND METHODS

(i) *Study area*

The present study was carried out in Durgapur Government College campus (23.54°N, 87.32°E, elevation 65 m MSL) situated amidst the Durgapur city of district Paschim Bardhhaman of West Bengal, India (Fig. 1). The total area of the campus is about 30 acres. Most of the area of the campus is covered by trees like *Ficus benghalensis, Ficus religiosa, Mangifera indica, Azaradicta indica, Polyalthia longifolia* and *Eucalyptus paniculata*. Garai et al. (2013) in their study from Durgapur Government College campus have reported the distribution and abundance of 24 different plant species. Apart from this several herbs and shrubs are abundantly found inside the campus. Some of the area inside this campus is barren in which different varieties of flowers are grown in winter. Soils of this area are mainly composed of three types – laterite soil with gravel, silty clayey soil and sandy clayey soil (Nayak & Roy, 2016). The temperature of the study site ranges between 8°– 43°C and average rainfall varies between 6–213 mm.

(ii) *Sampling of ant species*

Pitfall trapping has been found as the most effective sampling method of ants in open habitats which contains grasslands and scrub vegetation (Steiner et al., 2005). Methods employed to survey ground dwelling ants from the present study sites was fundamentally pitfall trapping method. Plastic vials of 8 cm diameter and 12 cm depth were buried under the soil with tip of the rim flushed with surrounding soil. Square lid of 10 cm^2 was placed at a height of 6 cm over the buried vials to keep rain and small vertebrates out of the pits. Ethanol was used as

Munis Entomology & Zoology
https://www.munisentzool.org/
ISSN 1306-3022

Mun. Ent. Zool.
(January, 2021)
© MRG

preservative inside the vials as it has been reported to be indifferent as attractant to different ant species (Greenslade & Greenslade, 1971). Five such setups were placed within the study location (keeping a minimum gap of 50 m) and were marked as S1, S2, S3, S4 and S5 based on the availability of sunlight and presence of vegetation (Fig. 1). Sampling was done for consecutive three months (April 2015 to June 2015) five days in a week (Monday to Friday). Only diurnal ant species were collected in a manner where setups were placed at 10:00 hrs in the morning and ants were harvested at 16:00 hrs in the afternoon of the same day. All ants were sorted manually and preserved in 70% alcohol. Ants were observed under compound microscope (Model: Olympus CH20i) fitted with a mechanical stage. Only worker ants were used for the identification purpose using suitable literature up to species level (Bingham, 1903; Holldobler & Wilson, 1990; Bolton, 1994). Data were pulled from four consecutive weeks to get the representative data of the month.

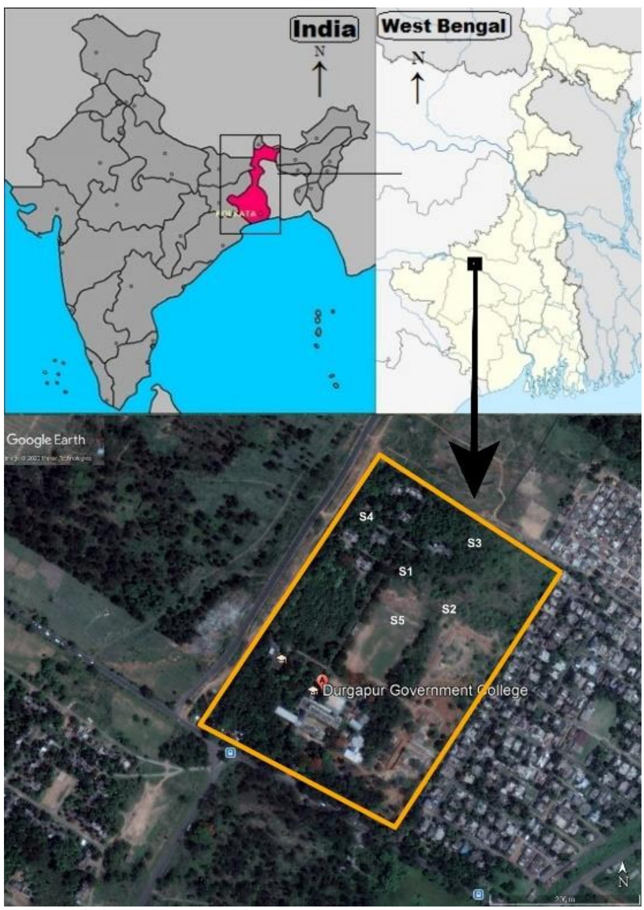

Figure 1. Location of the present study sites inside Durgapur Government College campus. Study sites have been marked as S1, S2, S3, S4 and S5 on the satellite image. Satellite image source: Google Earth.

(iii) *Physicochemical parameter analysis*

Seven different physicochemical parameters were analyzed from all the study sites during the present study. These tests were performed once in every week during the entire study period. Sampling were done during three different times (*viz.* 10:00 hrs, 13:00 hrs and 16:00 hrs) of the same day and values for each physicochemical factor were averaged to get the mean value of the day. Digital thermometer with metal probe was used to measure temperature of the soil surface at the ground level at the proximity of the study sites. Humidity of air was measured by hygrometer. Solar irradiance was measured by Lutron LX–101, digital LUX meter. Soil pH and conductivity were measured potentiometrically from filtered soil extracts by multimeter (Eutech Multi Pocket Tester PSCTEST35). For soil moisture content 5 g of fresh soil sample was weighed in a clean, dry Petri dish and covered with lid and kept in hot air oven at 105 °C for 24 hours. After drying, sample was cooled in a desiccator and weighed. The loss in weight represented the moisture content in the sample. The organic carbon present in soil samples were measured following potassium dichromate method (Black, 1965).

(iv) *Analysis of data*

Pearson product moment correlation was employed to identify the relationship, if any, between the physicochemical parameters and ant species at each study sites. The p values less than 0.05 has been considered significant and used for the current analyses. One–way Analysis of Variance (ANOVA) was used to check the physicochemical parameters and ant community composition of the study sites for significant variations (p <0.05). Cluster analysis was employed to determine the linkage between the sites both on the basis of physicochemical parameters and abundance of foraging ant species using the "nearest neighbour linkage" method. Canonical correspondence analysis (CCA) was used to evaluate indicator properties of ant subfamilies in response to physicochemical properties of the study sites. Indices relating to diversity, dominance, evenness and richness of the ant communities of the study sites were calculated (Krebs, 1999). The calculation of niche breadth for each ant species were done according to Levins' formula (Levins, 1968):

$B = Y^2/\sum p_j^2$

Where, Y is the total number of individual ants. p_j is the proportion of observations in each category (j) within a particular niche dimension.

(v) *Study of diversity indices*

Study of diversity indices are of fundamental importance for monitoring biodiversity and conservation. Four different diversity indices were used in the present study and the rationale of choice has been described below.

Shannon-Wiener Species Diversity Index [$H' = -\sum_{i=1}^{OS} pi \ln pi$]: To determine the broad estimate of species diversity which included both species richness and evenness.

Pielou's Evenness Index [$J' = \frac{H'}{\ln OS}$]: To determine how evenly the encountered species were distributed in the community.

Munis Entomology & Zoology
https://www.munisentzool.org/
ISSN 1306-3022
Mun. Ent. Zool.
(January, 2021)

Margalef's Richness Index [$D_{MARG} = \frac{OS-1}{\ln N}$]: To reflect the overall richness based on number of total species present in the community.

Simpson's Dominance Index [$D_{SIMP} = \sum_{i=1}^{OS} (pi)^2$]: To determine if there were any dominance which generally signifies the survival and spread of opportunistic/tolerant species.

[Where, *ni= importance value; N= total of importance values; pi= ni/N; OS= observed no. of species; S= total number of species; ln= natural logarithm*]

All the biodiversity indices were calculated in PAST version 3.25 Software (Hammer, 2017).

RESULTS

(i) *Comparative account of ant diversity*

A total of 31 ant species (with one subspecies *Diacamma rugosum sculptum*, Jerdon) under 18 genera and 5 subfamilies were recorded in the present study (Table 1). The most diverse ant subfamily recorded in the present study from all the study sites was Myrmicinae (47% species) followed by Formicinae (28% species) and Ponerinae (13% species) while Dolichoderinae (6% species) and Pseudomyrmecinae (6% species) were recorded as the least diverse ant subfamilies in the present study (Fig. 2). Though the diversity of ant species belonging to different subfamilies varied between different study sites the general pattern was Myrmicinae> Formicinae> Ponerinae> Dolichoderinae, Pseudomyrmecinae and it has been depicted in Fig. 3. The most diverse genus recorded in the present study was *Camponotus* (6 species) followed by genera *Crematogaster* (4 species) and *Monomorium* (3 species). *Pheidole*, *Carebara* and *Tetraponera* each had two representative species while rest of the genera were represented by single species which included *Diacamma rugosum* (Le Guillou) along with its subspecies *Diacamma rugosum sculptum* (Table 1).

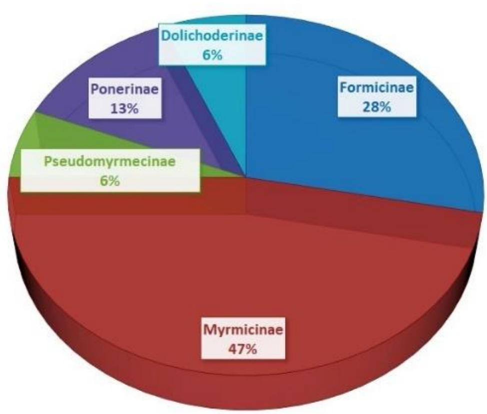

Figure 2. Proportionate distribution diagram of different ant subfamilies as recorded in the present study from Durgapur Government College campus.

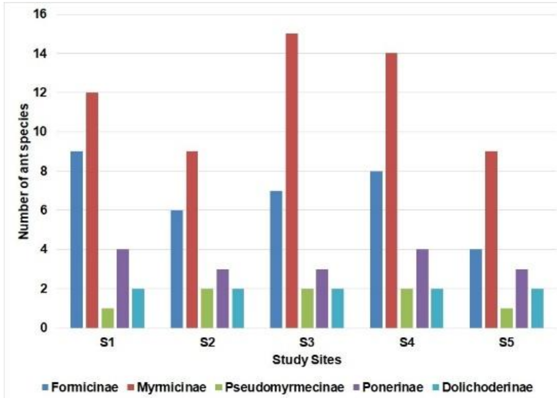

Figure 3. Diagram showing occurrence pattern of diverse ant species under different subfamilies from all the study sites (S1–S5) of Durgapur Government College campus.

Table 1. Mean density of ants (numbers per month) at the five study sites (S1–S5) under present investigation from Durgapur Government College Campus (I): Introduced species, (E) Endemic species to India.

Subfamily	Species (Scientific name)	Study sites				
		S1	S2	S3	S4	S5
Formicinae	*Camponotus compressus* (Fabricius, 1787)	18.67	14.00	12.00	12.00	5.33
	Camponotus irritans (Smith, 1857)	2.00	3.33	0.67	0.67	3.33
	Camponotus invidus Forel, 1892 (E)	8.00	0.00	2.67	3.33	0.00
	Camponotus rufoglaucus (Jerdon, 1851)	2.67	0.00	0.00	4.00	0.00
	Camponotus dolendus Forel, 1892	10.67	1.33	4.67	2.67	3.33
	Camponotus sericeus (Fabricius, 1798)	3.33	0.67	1.33	0.67	0.00
	Paratrechina longicornis (Latreille, 1802) (I)	0.67	0.00	0.67	0.67	0.00
	Oecophylla smaragdina (Fabricius, 1775)	1.33	2.00	12.00	16.67	0.00
	Anoplolepis gracilipes (Smith, 1857) (I)	1.33	0.67	0.00	0.00	1.33
Myrmicinae	*Crematogaster rothneyi* Mayr, 1879	14.00	2.67	2.67	9.33	0.67
	Crematogaster subnuda Mayr, 1879	2.67	0.00	2.67	6.67	1.33
	Crematogaster rogenhoferi Mayr, 1879	2.67	4.00	2.67	0.67	0.00
	Crematogaster aberrans Forel, 1892	4.67	4.67	12.00	2.00	0.00
	Monomorium pharaonis (Linnaeus, 1758) (I)	19.33	10.67	12.67	8.00	3.33
	Monomorium latinode Mayr, 1872	5.33	4.00	4.67	0.67	0.00
	Monomorium floricola (Jerdon, 1851)	6.00	0.00	1.33	6.67	1.33
	Trichomyrmex destructor (Jerdon, 1851)	0.00	0.00	2.00	0.00	0.67
	Solenopsis geminata (Fabricius, 1804) (I)	13.33	4.00	7.33	6.00	3.33
	Pheidole roberti Forel, 1902	6.67	4.67	2.67	8.00	0.00
	Pheidole sharpi Forel, 1902	3.33	3.33	7.33	4.00	0.00
	Carebara diversa (Jerdon, 1851)	0.67	0.67	0.67	0.67	2.00
	Carebara lignata Westwood, 1840	0.00	0.00	0.67	2.67	4.67
	Cardiocondyla nuda (Mayr, 1866)	0.00	0.00	2.00	1.33	2.67
	Tetramorium walshi (Forel, 1890)	0.67	0.00	1.33	1.33	0.00
Pseudomyrmecinae	*Tetraponera allaborans* (Walker, 1859)	0.00	4.67	2.67	0.67	0.00
	Tetraponera rufonigra (Jerdon, 1851)	0.67	1.33	0.67	1.33	1.33
Ponerinae	*Pseudoneoponera rufipes* (Jerdon, 1851)	6.67	6.67	7.33	4.67	6.00
	Platythyrea parallela (Smith, 1859)	12.00	2.67	4.67	6.00	3.33
	Diacamma rugosum (Le Guillou, 1842)	1.33	2.00	0.00	2.00	2.67
	Diacamma rugosum sculptum (Jerdon, 1851)	0.67	0.00	0.67	1.33	0.00
Dolichoderinae	*Tapinoma melanocephalum* (Fabricius, 1793)	1.33	2.67	2.67	1.33	0.67
	Technomyrmex albipes (Smith, 1861)	2.00	0.67	0.67	2.00	2.00

Munis Entomology & Zoology
https://www.munisentzool.org/
ISSN 1306-3022

Mun. Ent. Zool.
(January, 2021)
© MRG

The rank abundance curve revealed that *Camponotus compressus* was the most abundant ant species in the present study followed by *Monomorium pharaonis* and *Solenopsis geminata* (Fabricius) while the least abundant ant species were *Paratrechina longicornis* (Latreille), *Diacamma rugosum sculptum* and *Trichomyrmex destructor* (Jerdon) (Fig. 4). The study of niche breadth based on available resource states revealed that the maximum niche breadth was occupied by *Pseudoneoponera rufipes*, followed by *Tetraponera rufonigra* and *Camponotus compressus* while the minimum niche breadth was occupied by *Trichomyrmex destructor* followed by *Camponotus rufoglaucus* (Jerdon) and *Tetraponera allaborans* (Walker) (Fig. 5). Ant diversity among the five study sites varied to some degree and it was reflected in the study of diversity indices (Table 2). The Shannon Weiner general diversity score was found to be highest for S4 (2.997) followed by S3 (2.967) while the lowest was recorded for S5 (2.770). Similar patterns were also observed for Margalef's Richness Index where the highest scores were observed from S4 and S3 (6.206 and 6.054 respectively) while the lowest score was recorded for S5 (4.816). The highest score for Simpson's Dominance Index was recorded for S2 (0.079) followed by S5 and S1 (both having the score of 0.071) while the lowest score was observed for S4 (0.065). However, the study of Pielou's Evenness Index revealed the highest score from S5 (0.840) followed by S2 (0.735) while the lowest value was recorded from S1 (0.644).

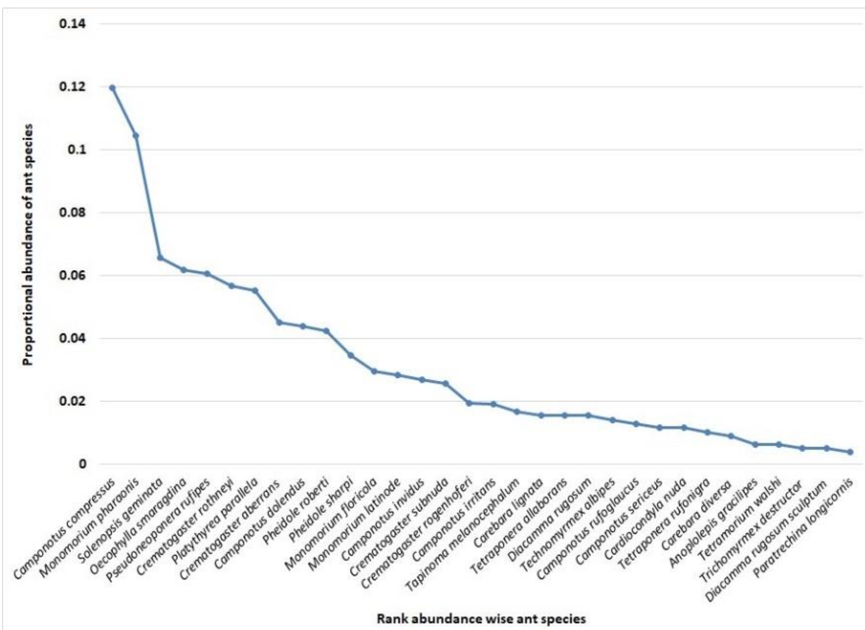

Figure 4. Rank abundance curve of all the ant species from Durgapur Government College campus.

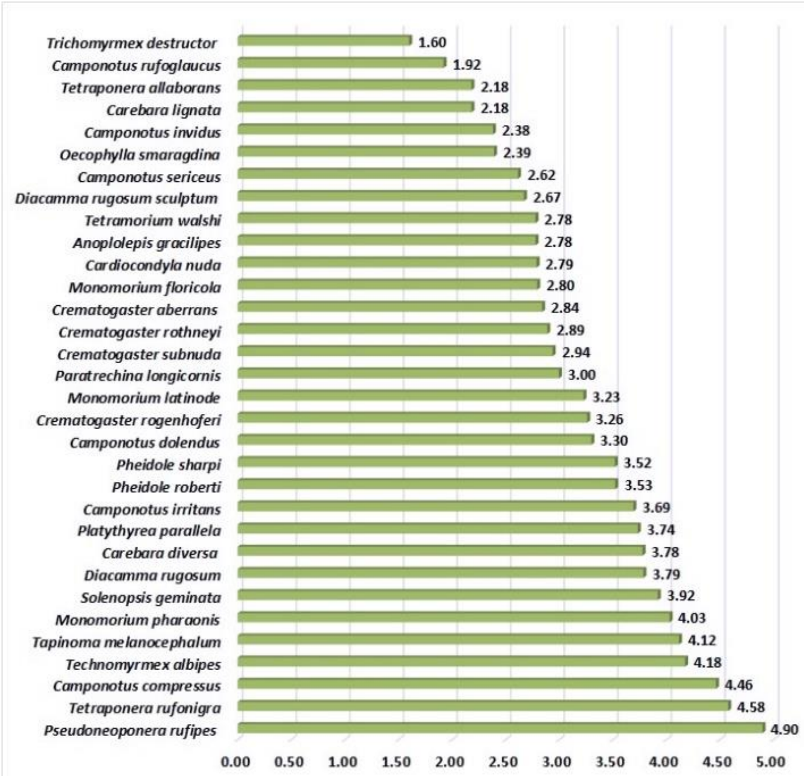

Figure 5. Diagram showing niche breadth of all the ant species based on available resource states of the five different study sites (S1–S5) from Durgapur Government College campus.

Table 2. Diversity indices of ant species from different study sites (S1–S5).

Diversity Indices	S1	S2	S3	S4	S5
Shannon Weiner Diversity	2.893	2.783	2.967	2.997	2.770
Simpson's Dominance Index	0.071	0.079	0.066	0.065	0.071
Pielou's Evenness Index	0.644	0.735	0.670	0.668	0.840
Margalef's Richness Index	5.456	4.910	6.054	6.206	4.816

This difference of ant diversity was also reflected in the one–way ANOVA study between the most diverse ant subfamilies (Myrmicinae, Formicinae and Ponerinae) from the different study sites (Table 3). Significant difference for subfamily Myrmicinae were noted between S1 and S2 and between S1 and S5. For subfamily Formicinae significant difference were noted between S1–S2, S1–S5, S3–S4 and S4–S5. However, no significant difference in ant diversity was noted among the different study sites for subfamily Ponerinae. Cluster analysis for different ant species from all the study sites revealed that site S2 and S5 were similar in ant diversity and so was S3 and S4 (Fig. 6). Ant diversity of S1 was somehow different and it was closer to the S3–S4 cluster than S2–S5 cluster.

Munis Entomology & Zoology
https://www.munisentzool.org/
ISSN 1306-3022

Mun. Ent. Zool.
(January, 2021)

Table 3. Computed F Values of One–Way ANOVA for ant subfamilies between the different study sites (S1–S5).

Subfamily	S1–S2	S1–S3	S1–S4	S1–S5	S2–S3	S2–S4	S2–S5	S3–S4	S3–S5	S4–S5
Formicinae	5.68*	0.89	0.15	6.20*	1.12	1.43	0.88	1.05	2.36	2.41
Myrmicinae	6.67*	0.84	1.81	7.04*	7.49	2.40	2.08	0.07	6.99*	8.46*
Ponerinae	0.99	1.20	1.12	0.95	0.16	0.35	0.27	0.10	0.03	0.30

The F values with asterisk (*) are significant at $p<0.05$.

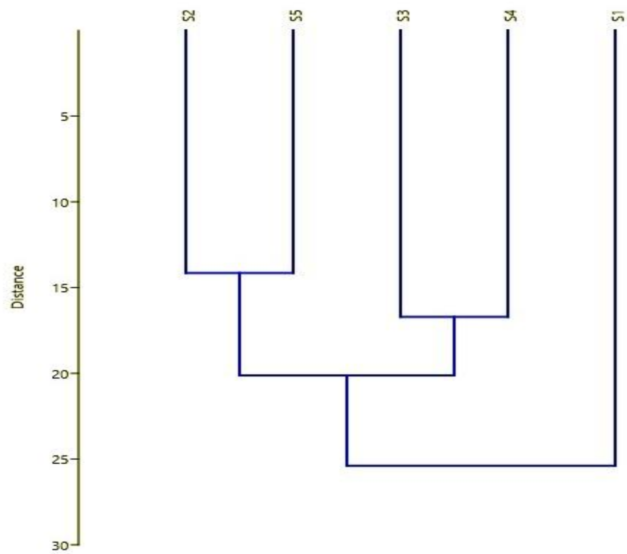

Figure 6. Cluster analysis diagram showing the linkage between the study sites on the basis of abundance of foraging ant species using the "nearest neighbour linkage" method from Durgapur Government College campus.

(ii) *Physicochemical parameters*

The mean values for physicochemical parameters of the different study sites during the present study has been depicted in Table 4. The values for these physicochemical parameters varied between the different study sites considerably. Apart from relative humidity the values for all other physicochemical parameters varied significantly among the different study sites (Table 5). Based on physicochemical parameters cluster analysis showed that S2 and S5 were in the same cluster with S3 being closely associated while S1 and S4 were in another cluster (Fig. 7).

(iii) *Relationship between ant diversity and physicochemical parameters*

The influence of physicochemical parameters on ant diversity of different study sites was evident from the study of correlations (Table 6). Ant diversity was found to be significantly negatively influenced by soil surface temperature (r= –0.72) and solar irradiance (r= –0.81). Apart from this pH was found to have a negative influence on ant diversity. All the other physicochemical parameters had positive correlation with ant diversity of which soil organic carbon was statistically significant (*r*= 0.84). The study of CCA was in confirmation with these findings where conductivity, relative humidity, soil moisture and soil organic carbon were found in the same half of the graph while solar irradiance, soil surface temperature and pH were noted in the opposite half (Fig. 8). Moreover, CCA revealed that subfamilies with the highest representatives (Myrmicinae and Formicinae) were influenced most by conductivity, relative humidity, soil moisture and soil organic carbon while rest of the ant subfamilies recorded in the present study (Ponerinae, Dolichoderinae and Pseudomyrmecinae) were influenced most by solar irradiance, soil surface temperature and pH. Additionally, the CCA plot showed the close association of S1, S3 and S4 while S2 and S5 were close together.

Table 4. Physicochemical parameters recorded from different study sites (S1–S5) during the present study. (SST–Soil surface temperature; HUMID–Humidity; SR–Solar irradiance; COND–Conductivity; Moist–Soil moisture content; OC–Soil organic carbon).

Factors	**Unit**	**S1**	**S2**	**S3**	**S4**	**S5**
		Mean± SD	**Mean± SD**	**Mean± SD**	**Mean± SD**	**Mean± SD**
SST	ºC	34.55±1.39	34.33±1.53	33.00±2.00	33.10±2.65	39.67±2.08
HUMID	%	55.33±8.08	55.00±6.08	54.33±8.14	51.00±8.19	51.33±6.43
SR	Lux	11317±918	24667±306	21167±764	10167±289	24733±231
pH	–	6.36±0.17	5.99±0.03	5.94±0.05	6.16±0.17	6.74±0.11
COND	mS/m	61.61±7.04	50.53±5.98	53.92±12.3	66.89±14.9	42.40±2.35
MOIST	%	7.83±0.67	8.00±1.39	7.73±0.57	9.37±0.74	5.98±0.43
OC	%	0.94±0.05	0.25±0.05	0.80±0.06	1.08±0.18	0.32±0.01

Table 5. Computed F Values of One–Way ANOVA for physicochemical parameters between the different study sites (S1–S5). (SST–Soil surface temperature; HUMID–Humidity; SR–Solar irradiance; COND–Conductivity; Moist–Soil moisture content; OC–Soil organic carbon).

Factors	**S1–S2**	**S1–S3**	**S1–S4**	**S1–S5**	**S2–S3**	**S2–S4**	**S2–S5**	**S3–S4**	**S3–S5**	**S4–S5**
SST	0.08	12.0	3.20	13.03	1.23	2.28	64*	0.00	12.9	21.1*
HUMID	0.07	3.00	8.89	12.0	0.21	4.00	17.3	14.29	9.00	0.07
SR	199*	40.4*	0.92	189*	118*	2035*	1.00	484*	125*	3131*
pH	10.6	20.4*	4.95	6.82	2.02	2.57	231*	9.61	228*	32.6*
COND	253*	6.23	1.32	19.5*	0.82	9.76	4.40	73.0*	2.48	7.17
MOIST	0.14	3.00	49.2*	83.8*	0.30	5.58	12.6	49.0*	136*	86.7*
OC	1331*	20.6*	2.76	385*	435*	93.1	6.02	6.40	271*	49.0*

The F values with asterisk (*) are significant at $p<0.05$.

Table 6. Correlations between the physicochemical parameters and diversity of ants at the study sites (S1–S5). (SST–Soil surface temperature; HUMID–Humidity; SR–Solar irradiance; COND–Conductivity; Moist–Soil moisture content; OC–Soil organic carbon; ANTD–Ant diversity).

	SST					
HUMID	−0.38	HUMID				
SR	0.50	0.09	SR			
PH	0.89*	−0.48	0.06	PH		
COND	−0.79*	0.53	0.13	−0.96*	COND	
MOIST	−0.88*	0.03	−0.68	−0.68	0.47	MOIST	
OC	−0.62	−0.09	−0.92*	−0.23	0.11	0.66	OC
ANTD	−0.72*	0.45	−0.81*	−0.40	0.30	0.62	0.84*

Correlations significant at $p<0.05$ are mentioned with asterisk (*). Negative correlations are denoted by "–".

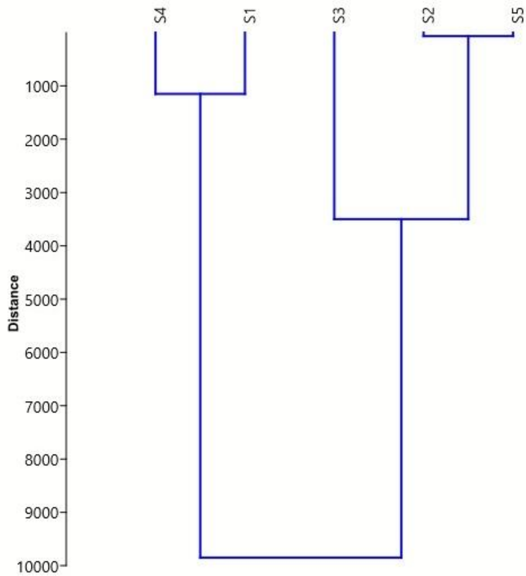

Figure 7. Cluster analysis diagram showing the linkage between the study sites on the basis of physicochemical variables using the "nearest neighbour linkage" method from Durgapur Government College campus.

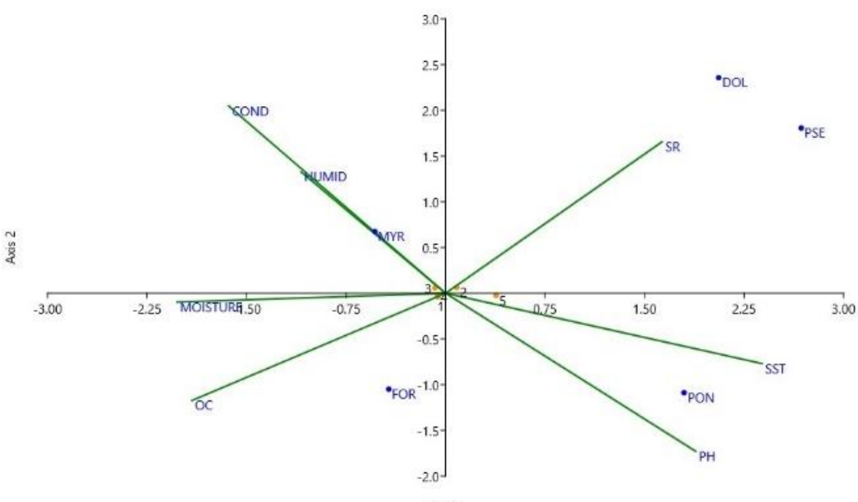

Figure 8. Canonical correspondence analysis (CCA) plot showing influences of physicochemical properties of the study sites on ant subfamilies of the five different study sites (S1–S5) from Durgapur Government College campus.

DISCUSSION

The present study recorded only 8% of total ant species reported previously to occur in the state of West Bengal (Bharati et al., 2016). However, the present findings were important since no previous records were there from the district of Paschim Bardhaman regarding diversity of ants. In a similar study Ramesh et al. (2009) have reported exactly 31 ant species as in the present study from Department of Atomic Energy campus, Kalpakkam, Tamil Nadu, India carried out during four summer months (March – June). Again, Chanda (2017) have reported 34 ant species from Midnapore town and adjoining areas of West Bengal during a span of one–year study. Azhagu Raj et al. (2017) in their study of two winter months (January and February) from Pachaiyappa's College, Kanchipuram, Tamil Nadu, India have reported 10 species of ant. However, higher species diversity has also been reported in other studies mainly from Western Ghats and Bangalore and adjoining areas (Gadhakar et al., 1993; Sunil Kumar et al.,1997). Relatively lower diversity as recorded in the present study may be attributed to the fact that only ground dwelling ants were surveyed in the present study. This simply means that ant species which were either completely subterranean or arboreal were not accounted in the present study. Also, only diurnal sampling was done which implies that if there were any crepuscular or nocturnal ant species available from the present study location those were altogether missed. Moreover, as pitfall was used as the only sampling method there were every chance of missing a few species by chance factor alone. Additionally, regular human activities around the sampling sites were a common event and this might have negatively influenced the optimum sampling to some degree. Similar findings have been also made by other researchers (Wang et al., 2000). Also, only three summer months were surveyed in the present study, hence, this may be hoped that yearlong studies covering larger geographic area around the present study location will have every chance of uncovering more species.

The present finding of Myrmicinae being the most dominant ant subfamily followed by Formicinae and Ponerinae while Dolichoderinae and Pseudomyrmecinae being the least diverse ant subfamilies corroborated well with previous studies from other states of India (Ramesh et al., 2009; Chavhan and Pawar 2011). However, these findings were different from those made from the Amazonian forest where Ponerinae has been reported as the most dominant ant subfamily (Majer and Delabie 1994). Looking at the global scenario the most abundant ant genera have been reported as *Camponotus*, *Pheidole* and *Crematogaster* (Wilson, 1976). However, there were variations to this as *Monomorium* has been reported as the most dominant taxa by Ramesh et al. (2009) while Chavhan & Pawar (2011) have reported *Crematogaster* as the most dominant ant species in their study. Thus, it can be said that the present findings were in confirmation with the previous studies. *Camponotus* was recorded as the most diverse genus in the present study. Globally more than 1000 species with nearly 500 subspecies has been described for this genus (Bolton 2012). Predictions have been made that it could be the largest ant genus (Hita Garcia et al., 2013). *Camponotus compressus* being the most abundant ant species in the present study fits well with these facts. Previous studies from other parts of West Bengal have also reported *Camponotus compressus* as the most dominant ant species (Hazra, 2018; Saha et al., 2019). The second most abundant ant species recorded in the present study was *Monomorium pharaonis*. Mention may be made that *Monomorium* too was a diverse ant group and *Monomorium pharaonis* has been known as a domestic pest species that has been reported to occur indoor in temperate regions and both in indoor and outdoor in tropical region (Wetterer, 2010). The next most abundant species *Solenopsis geminata* better known as 'tropical fire ant' have been found to occur in sunny open land as well as forested region in large numbers (Trager, 1991).

Results obtained from the study of diversity indices were interesting to note. Shannon Weiner Diversity score of more than 2.5 for all the study sites indicated a handsome ant diversity and study site S3 and S4 were most diverse. Higher diversity was also supported by Margalef's Richness Index score for S3 and S4. Ant species recorded in the present study were mostly evenly distributed among different study sites and has been reflected in the Pielou's Evenness Index. This was also evident from the Simpson's Dominance Index score which were very low indicating that dominant species were absent in the current study. Mention may be made that both Shannon measures ($H^{/}$) and Simpson's index (D_{SIMP}) consider the proportional abundance of species. However, $H^{/}$ was more sensitive to rare insect species, whereas D_{SIMP} puts emphasis on the common species (Roy et al., 2012).

Ant species recorded from different study sites were not homogeneous and it was reflected in the ANOVA results. So, what might have resulted this uneven distribution of ants within the relatively small study area? Mention may be made that sampling were restricted only to the bright hours of the day of hot dry summer months in the present study hence, there were every chance that solar irradiance and soil surface temperature could have shaped the distribution pattern. Since, ants are poikilotherms they depend on ambient temperature for certain activities including foraging (Bernstein, 1974). It has been reported that a rise of 10°C in temperature doubles the respiration rate in ants (Peakin & Josens, 1978). Solar radiation also has been reported as an important factor to control foraging of ants (Pol & de Casenave, 2004). Results obtained from the study of physicochemical parameters clearly indicated that study areas with higher solar irradiance and higher soil surface temperature harboured lower ant diversity whereas higher relative humidity positively influenced ant aggregation. Previous studies have also reported foraging activity to be negatively correlated with ambient temperature and positively correlated with ambient relative humidity, however, no such correlation was recorded with solar radiation in these studies (Chong & Lee, 2006, 2009). Role of pH on ants have been reported in few studies and it has been found that ants prefer a neutral pH and acts towards it through various activities (Frouz & Jilková, 2008). Soils recorded in the presents study from all the study sites were slightly acidic in nature and this might have resulted in the negative correlation between the foraging ants and pH of soil. Present study also revealed positive correlation between foraging ants and soil conductivity, soil moisture and soil organic carbon. Higher humidity and higher soil moisture have been reported to influence the occurrence of ant community positively (Kharbani & Ray Hajong, 2013). Present findings indicated that foraging ants due to higher ambient temperature and solar irradiance preferred humid areas with lower temperature and higher soil moisture content. This physical parameters in turn influenced other parameters like soil conductivity and soil organic carbon. Study sites S2 and S5 received higher solar radiation due to less vegetation cover and consequently temperature was higher in these areas. Coupled with these were lower humidity, lower soil moisture and lower organic matter. Accordingly, study sites S2 and S5 resulted in lower ant species. On the other hand, study sites S1, S3 and S4 had differing physicochemical conditions with higher vegetation cover and harboured higher ant species.

Regarding niche occupancy and using available resources it may be mentioned that larger sized ants have been reported to cover larger foraging areas (Hughes et al., 2002; Davidson et al., 2003). The present finding of *Pseudoneoponera rufipes* followed by *Tetraponera rufonigra* and *Camponotus compressus* occupying the maximum niche breadth corroborated well with that. However, body size alone could not have determined the distribution pattern since, larger body sized *Camponotus rufoglaucus* and *Tetraponera allaborans* were among the species having smaller niche breadth. Thus, inference may be drawn that species those were generalist in their foraging and feeding pattern showed broad niche while those with specialized foraging and feeding pattern showed narrow niche breadth. Additionally, vegetation pattern, availability of food resources and edaphic conditions along with several biotic factors must have created micro–niche conditions for the occurrence and distribution pattern of ant species from the present study location. These findings are similar with that made by Kumar & Mishra (2008) where they have reported that composition of ants was habitat specific and got influenced by vegetation. To conclude it is worth mentioning that the findings made during the present study were interesting, however, more intensive studies were required from the present study location for a better understanding of distribution, abundance, behavior and ecology of ants.

ACKNOWLEDGEMENTS

The authors thankfully acknowledge the help and support extended by the Director of Public Instruction Government of West Bengal, India. The authors also would like to express their thanks and acknowledge Prof. A. K. Pal, Ex–Officer–in–Charger, Durgapur Government College and Prof. Swapan Sarkar, Officer–in–Charger, P. R. Thakur Government College for their constant motivation and sustained goodwill. The authors also wish to thank Dr. Moitreyee Chakrabarty, Head, P. G. Department of Conservation Biology for her unconditional help and support.

LITERATURE CITED

Azhagu Raj R., Sathish, R., Prakasam, A., Krishnamoorthy, D. & Balachandar, M. 2017. Diversity and distribution of Ant species (Hymenoptera: Formicidae), in Pachaiyappa's College, Kanchipuram, Tamil Nadu, India. Journal of Entomology and Zoology Studies, 5 (1): 459-464.

Bernstein, R. A. 1974. Seasonal food abundance and foraging activity in some desert ants. The American Naturalist, 108: 490-498.

Bharti, H., Guénard, B., Bharti, M. & Economo, E. P. 2016. An updated checklist of the ants of India with their specific distributions in Indian states (Hymenoptera, Formicidae). ZooKeys, 551: 1-83.

Bingham C. T. 1903. The Fauna of British India, including Ceylon and Burma. Hymenoptera, Vol–II, Ants and Cuckoo–wasps, Taylor and Francis, London, 508 pp.

Black, C. A. 1965. Methods of soil analysis. Part I, American Society of Agronomy, Madison, Wisconsin, USA, 1572 pp.

Bolton, B. 1994. Identification guide to the ant genera of the world. Cambridge: Harvard University Press, Massachusetts, 222 pp.

Bolton, B. & Fisher, B. L. 2012. Taxonomy of the cerapachyine ant genera *Simopone* Forel, *Vicinopone* gen. n. and *Tanipone* gen. n. (Hymenoptera: Formicidae). Zootaxa, 3283: 1-101.

Chanda, A. 2017. A study on ants (Hymenoptera: Formicidae) of Medinipur, West Bengal, India. International Journal of Entomology Research, 2 (5): 1-4.

Chavhan, A. & Pawar, S. S. 2011. Distribution and diversity of ant species (Hymenoptera: Formicidae) in and around Amravati City of Maharashtra, India. World Journal of Zoology, 6 (4): 395-400.

Chong, K. F. & Lee, C. Y. 2006. Food preferences and foraging activity of field populations of a pest ant, *Tapinoma indicum* (Hymenoptera: Formicidae). Sociobiology, 48: 875-883.

Chong, K. F. & Lee, C. Y. 2009. Influences of temperature, relative humidity and light intensity on the foraging activity of field populations of the longlegged ant, *Anoplolepis gracilipes* (Hymenoptera: Formicidae). Sociobiology, 54 (2): 531-539.

Davidson, D. W., Cook, S. C., Snelling, R. R. & Chua T. H. 2003. Explaining the abundance of ants in lowland tropical rainforest canopies. Science, 300 (5621): 969-972.

Frouz, J. & Jilková, V. 2008. The effect of ants on soil properties and processes (Hymenoptera: Formicidae). Myrmecological News, 11: 191-199.

Gadagker, R., Nair, P. & Bhat, D. M. 1993. Ant species richness and diversity in some selected localities in Western Ghats, India. Hexapoda, 5 (2): 79-94.

Garai, M., Kar, D., Palit, D. & Banerjee, A. 2013. Phyto–sociological assessment of vegetation of Durgapur Government College campus, Durgapur, West Bengal, India. International Journal of Engineering Research and Applications, 3 (6): 835-840.

Greenslade, P. & Greenslade, P. J. M. 1971. The use of baits and preservatives in pitfall traps. Australian Journal of Entomology, 10: 253-60.

Hammer, Ø. 2017. Paleontological Statistics. Natural History Museum, University of Oslo. http://folk.uio.no/ohammer/past (assessed on 09.03.2020).

Hazra, K. 2018. Diversity of ants in two different sites at Contai municipality, Purba Medinipur, West Bengal, India. International Journal of Creative Research Thoughts, 6 (2): 566-571.

Hita Garcia, F., Wiesel, E. & Fischer, G. 2013. The ants of Kenya (Hymenoptera: Formicidae)–faunal overview, first species checklist, bibliography, accounts for all genera, and discussion on taxonomy and zoogeography. Journal of East African Natural History, 101 (2): 127-222.

Hölldobler, B. & Wilson, E. O. 1990. The Ants, Belknap Press of Harvard University Press, 732 pp.

Hughe, W. O. H., Eilenberg, J. & Boomsma, J. J. 2002. Trade–offs in group living: transmission and disease resistance in leaf–cutting ants. Proceedings of the Royal Society London B, 269 (1502): 1811-1819.

Kharbani, H. & Hajong, S. Ray. 2013. Seasonal patterns in ant (Hymenoptera: Formicidae) activity in a forest habitat of the West Khasi Hills, Meghalaya, India. Asian Myrmecology, 5: 103-112.

Kiester, A. R., Scott, J. M. Csuti, B., Noss, R. F., Butterfield, B., Sahr, K. & White, D. 1996. Conservation prioritization using GAP data. Conservation Biology, 10: 1332-1324.

King, J. R., Warren, R. J. & Bradford, M. A. 2013. Social insects dominate eastern temperate hardwood forest macroinvertebrate communities in warmer regions. PLoS One, 8: e75843.

Krebs, C. J. 1999. Ecological Methodology. Addison–Wesley Educational Publishers, Second Edition, Boston, 620 pp.

Kumar, D. & Mishra, A. 2008. Ant community variation in urban and agricultural ecosystems in Vadodara District (Gujarat State), western India. Asian Myrmecology, 2: 85-93.

Lach, L., Parr, C. L. & Abbott, K. L. 2010. Ant Ecology, 1st edition, Oxford University Press, Oxford, 402 pp.

Lawton, J. H., Bignell, D. E., Bolton, B., Bloemers, G. F., Eggleton, P., Hammond, P. M., Hodda, M., Holt, R. D., Larsen, T. B., Mawdsley, N. A., Stork, N. E., Srivastava, D. S. & Watt, A. D. 1998. Biodiversity inventories, indicator taxa, and effects of habitat modification in tropical forest. Nature, 391: 72-76.

Levins, R. 1968. Evolution in changing environments, Princeton, NJ, Princeton University Press, 120 pp.

Lyford, W. H. 1963. Importance of ants to brown podzolic soil genesis in New England, Harvard Forest paper 7, Harvard University Press, MA, USA, 18 pp.

Majer, J. D., Orabi, G. & Bisevac, L. 2007. Ants (Hymenoptera: Formicidae) pass the bioindicator scorecard. Myrmecological News, 10: 69-76.

Majer, J. D. & Delabie, J. H. C. 1994. Comparison of the ant communities of annually inundated and terra firme forests at Trombetas in the Brazilian Amazon. Insect Society, 41: 343-359.

Nayak, A. K. & Roy, U. S. 2016. An observation on the odonata fauna of the Asansol–Durgapur industrial area, Burdwan, West Bengal, India. Journal of Threatened Taxa, 8 (2): 8503-8517.

Noss, R. F. 1990. Indicators for monitoring biodiversity: a hierarchical approach. Conservation Biology, 4: 355-364.

Peakin, G. J. & Josens, G. 1978. Respiration and energy flow. In: Brian MV (ed), Production ecology of ants and termites, IBP 13, Cambridge University Press, Cambridge London New York Melbourne, pp. 111-164.

Pearson, D. L. 1994. Selecting indicator taxa for the quantitative assessment of biodiversity. Philosophical Transactions of the Royal Society of London B, 345: 75-79.

Pol, R. & de Casenave, J. L. 2004. Activity patterns of harvester ants *Pogonomyrmex pronotalis* and *Pogonomyrmex rastratus* in the central Monte desert, Argentina. Journal of Insect Behavior, 17: 647-661.

Ramesh, T., Jahir Hussain, K., Selvanayagam, M. & Satpathy, K. K. 2009. Diversity of the ground inhabiting ant fauna at Department of Atomic Energy campus, Kalpakkam (Tamil Nadu). Halteres, 1 (1): 1-9.

Roberts, L. 1991. Ranking the rain forests. Science, 251: 1559-1560.

Roy, U. S., Mukherjee, M. & Mukhopadhyay, S. K. 2012. Butterfly diversity and abundance with reference to habitat heterogeneity in and around Neora Valley National Park, West Bengal, India. Our Nature, 10: 53-60.

Saha, S. Roy, T. & Raychaudhuri, D. 2019. Ant faunal diversity of Bibhutibhushan Wildlife Sanctuary, North 24 Parganas, West Bengal, India. World Scientific News, 120 (2): 81-110.

Steiner, F. M., Schlick-Steiner, B. C., Moder, K., Bruckner, A. & Christian, E. 2005. Congruence of data from different trapping periods of ant pitfall catches (Hymenoptera: Formicidae). Sociobiology, 46: 105-16.

Stork, N. E. 2018. How many species of insects and other terrestrial arthropods are there on earth? Annual Review of Entomology, 63: 31-45.

Sunil Kumar, M., Srihari, K. T., Nair, P., Varghese, T. & Gadagker, R. 1997. Ant species richness at selected localities of Bangalore. Insect environment, 3 (1): 3-5.

Trager, J. C. 1991. A revision of the fire ants, *Solenopsis geminata* group (Hymenoptera: Formicidae: Myrmicinae). Journal of the New York Entomological Society, 99: 141-198.

Wang, C., Strazanac, J. & Butler, L. 2000. Abundance, diversity, and activity of ants (Hymenoptera: Formicidae) in Oak–Dominated mixed Appalachian forests treated with microbial pesticides. Environmental Entomology, 29 (3): 579-586.

Wetterer, J. K. 2010. Worldwide spread of the pharaoh ant, *Monomorium pharaonis* (Hymenoptera: Formicidae). Myrmecological News, 13: 115-129.

Wilson, E.O. 1976. Which are the most prevalent ant genera? Studia Entomologica, 19: 187-200.