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Exploring ant diversity with fuzzy logic and python

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Abstract
Fuzzy logic can be used to identify patterns in the data, which can be used to better understand the diversity of a particular ecosystem. This study examines the diversity of ants in different sites of Palayamkottai using the Combined Effect Quantity Dependent Data Matrix (CEQD-Matrix). Initial raw data is collected and transformed into an Average Quantity Dependent Data matrix (AQD Matrix) by taking ants' names as rows and point count sites as columns. A defined quantity dependent data matrix (RQD Matrix) is then generated using mean and standard deviation methods. Finally, a Combined Effect Quantity Dependent Data matrix (CEQD Matrix) is produced to show the cumulative effect of all the entries. Python is used to generate the graphs of the RQD Matrix and CEQD Matrix. It was found that the species *Tetraponera rufonigra* predominantly occupied the all sites, followed by *Oecophylla smaragdina*. The matrix was also used to predict the effects of anthropogenic disturbances on the ant diversity.

Keywords: Ants, fuzzy logic, python and CEQD matrix

1. Introduction

The Formicidae consists of hymenopterans commonly called Ants. Ants are found everywhere. Ant communities show an excellent difference within the number of species and colony density from place to place Bruhl *et al.* [1]. The Hymenoptera is a significant order of holometabolous insects. That is, they undergo an entire metamorphosis with distinct egg, larvae, pupa and adult stages Quicke [2]. All the known species of ants belong to Formicidae and are social insects. Ants are most important invertebrates which play a dynamic role in the alteration of soil ecosystem diversity Quicke [2].

Simpson and Shannon-Weiner indices are limited by the number of species captured in the sample. If the sample does not capture a full representation of the species present, the index values may not accurately reflect the true diversity of the area. Both the Simpson and Shannon-Weiner indices are limited by the size of the area being sampled. If the sample area is too small, the index values may not accurately reflect the diversity in the larger area. Fuzzy matrix can be used to compare the species richness and abundance of different areas Juan A. Balbuena *et al.* [3].

Fuzzy logic can be used to identify patterns in the data, which can be used to better understand the diversity of a particular ecosystem De Cáceres, *et al.* [4] Fiorentino Dario *et al.* [5]. Fuzzy logic allows us to think about things in terms of degrees of membership and gradations of similarity Bagnaro *et al.* [6]; Bandelj *et al.* [7]. Bart Kosko [8] Vasantha Kandasamy [9] explored socioeconomic and psychological issues with the help of fuzzy matrices and fuzzy cognitive maps. They proposed four categories of matrices, which were Initial Raw Data Matrix (IRDM), Average Time Dependent Data Matrix (ATDM), Refined Time Dependent Data Matrix (RTDM), and Combined Effect Time Dependent Data Matrix (CETDM). These matrices were utilized to examine the various problems were successively applied in medical sciences, engineering sciences, Industry and biological diversity studies.

Victor Devadoss *et al.* [10] used a combined effect time dependent data matrix to examine the dimensions of women's personalities in Chennai. Narayanamoorthy [11] applied the same data matrix to estimate the maximum age group of silk weavers as bounded labours. Similarly, Narayanamoorthy *et al.* [12] used a fuzzy combined effect time dependent data matrix to estimate the maximum age group of endosulfan pesticide victims in Kerela. Kokila [13] used a fuzzy matrix combined effect time dependent data matrix to study student's information gathering attitudes. Jon Arockiaraj and Murali [14] reported that a fuzzy matrix analysis was used to analyze seasonal fishing in Cuddalore. Iftikhar *et al.* [15] employed a combined effect time dependent data matrix to estimate the maximum age group of stressed students studying in Higher Education.

Radhika *et al*. [16, 17] utilized a CETD data matrix analysis to study the risk factors of breast cancer and its uses in aquaculture.

In this study, we used the combined effect quantity dependent data matrix for the Ants diversity in the different sites of Palayamkottai. The present study focus on whether the Inter or intra-species competitions, landscape patterns, soil quality and food preference in different sites can alter the diversity and distribution of ants by using fuzzy combined effect quantity dependent data matrix.

2. Observed attributes with short descriptions

Ants were collected using a brush and forceps during daytime in between 7.30 am to 4 pm twice in every month by Pitfall Trap (PT), Bait Trap (BT) and All-Out Search Method (AOSM) Azhagu Raj *et al.* [18]. The ant diversity raw data from the sites S1, S2, S3 and S4 were used for this study.

3. Preliminaries

This section includes some basic definitions and notations on different types of fuzzy matrices.

Definition 2.1. An initial raw data matrix (IRDM) is the collection of initial data into matrix form by taking bird's common name as rows and point count sites as the columns.

Definition 2.2. An average quantity dependent data matrix (AQDM) is derived by transforming initial raw-data matrix by dividing each row with the percentage difference in given point count sites.

Definition 2.3. A number of refined quantity dependent data matrices (RQDMs) are derived by varying a parameter $\alpha \in [0, 1]$ and using mean and standard deviation methods. The only entries of refined quantity dependent data matrices are -1, 0 or 1.

Definition 2.4. A transformation of average quantity dependent data matrix into a number of refined quantity dependent data matrices by varying a parameter$\alpha \in [0, 1]$ and using mean and standard deviation is obtained using the following mathematical formulae:

If $a_{ij} \leq \mu_j - \alpha\sigma_j$ then $b_{ij} = -1$

Else $a_{ij} \geq \mu_j + \alpha\sigma_j$ then $b_{ij} = 1$

Elseif $a_{ij} \in (\mu_j - \alpha\sigma_j, \mu_j + \alpha\sigma_j)$ then $b_{ij} = 0$

Where μ_j simple mean and$\sigma_j$is standard deviation of corresponding to each column of the average quantity dependent data matrix, respectively.

Definition 2.5. A combination of different refined quantity dependent-data-matrices by varying $\alpha \in [0, 1]$ gives cumulative effect of all the entries and known as combined effect quantity dependent data matrix (CEDM).

4. Methodology

Step 1: Using entries of Ants name as rows and point count locations as columns, we provide the raw data as a matrix.

Step 2: The initial matrix is transformed into an average quantity dependent data (AQD) matrix in the second stage.

Step 3: To make the computations simpler and easier, we apply basic average techniques in the third step to transform the above-average quantity-dependent data matrix into a matrix with entries$b_{ij} \in \{-1,0,1\}$. This matrix has the term Refined Quantity Dependent Data Matrix (RQD Matrix).

Step 4: Using the RQD matrices, we create the Combined Effect Quantity Dependent Data Matrix (CEQD Matrix), which shows the cumulative effect of all these entries.

Step 5: Finally, we derive the CEQD matrix's row sums. Each stage's tables are self-explanatory. Using Python, the graphs of the RQD matrix and CEQD matrix are shown.

Table 1: Initial raw data matrix of order 8 x 4 based on Ant diversity

Ant species name	S1	S2	S3	S4
Tetraponera rufonigra (Jerdon, 1851)	36	22	26	23
Paratrechina longicornis (Latreille, 1802)	21	31	15	12
Camponotus mitis (Smith, 1858)	14	15	21	31
Camponotus barbatus taylori Forel, 1892	18	12	14	13
Solenopsis geminata (Fabricius, 1804)	35	16	10	18
Myrmicaria brunnea Saunders, 1842	28	20	17	15
Trichomyrmex glaber (Andre, 1883)	16	12	11	21
Oecophylla smaragdina (Fabricius, 1775)	12	18	36	41

Table 2: AQDM of order 8 x 4 based on Ant diversity

Ant species name	S1	S2	S3	S4
Tetraponera rufonigra (Jerdon, 1851)	0.36	0.22	0.26	0.23
Paratrechina longicornis (Latreille, 1802)	0.21	0.31	0.15	0.12
Camponotus mitis (Smith, 1858)	0.14	0.15	0.21	0.31
Camponotus barbatus taylori Forel, 1892	0.18	0.12	0.14	0.13
Solenopsis geminata (Fabricius, 1804)	0.35	0.16	0.1	0.18
Myrmicaria brunnea Saunders, 1842	0.28	0.2	0.17	0.15
Trichomyrmex glaber (Andre, 1883)	0.16	0.12	0.11	0.21
Oecophylla smaragdina (Fabricius, 1775)	0.12	0.18	0.36	0.41

Table 3: Column wise mean and standard deviation of AQDM

	S1	S2	S3	S4
Mean	0.225	0.1825	0.1875	0.2175
Standard Deviation	0.09381	0.06251	0.08714	0.09925

Obtaining various refined quantity-dependent data matrices by taking $\alpha = 0.25, 0.5, 0.75$ and computing their related row sums as column matrices.

Obtained RQD matrix for $\alpha = 0.25$ obtained row sum matrix

$$\begin{bmatrix} 1 & 1 & 1 & 0 \\ 0 & 1 & -1 & -1 \\ -1 & -1 & 1 & 1 \\ -1 & -1 & -1 & -1 \\ 1 & -1 & -1 & -1 \\ 1 & 1 & 0 & -1 \\ -1 & -1 & -1 & 0 \\ -1 & 0 & 1 & 1 \end{bmatrix} = \begin{bmatrix} 3 \\ -1 \\ 0 \\ -4 \\ -2 \\ 1 \\ -3 \\ 1 \end{bmatrix}$$

Obtained RQD matrix for $\alpha = 0.5$ obtained row sum matrix

$$\begin{bmatrix} 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & -1 \\ -1 & -1 & 0 & 1 \\ 0 & -1 & -1 & -1 \\ 1 & 0 & -1 & 0 \\ 1 & 0 & 0 & -1 \\ -1 & -1 & -1 & 0 \\ -1 & 0 & 1 & 1 \end{bmatrix} = \begin{bmatrix} 3 \\ 0 \\ -1 \\ -3 \\ 0 \\ 0 \\ -3 \\ 1 \end{bmatrix}$$

Obtained RQD matrix for $\alpha = 0.75$ obtained row sum matrix

$$\begin{bmatrix} 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & -1 \\ -1 & 0 & 0 & 1 \\ 0 & -1 & 0 & -1 \\ 1 & 0 & -1 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & -1 & -1 & 0 \\ -1 & 0 & 1 & 1 \end{bmatrix} = \begin{bmatrix} 2 \\ 0 \\ 0 \\ -2 \\ 0 \\ 0 \\ -2 \\ 1 \end{bmatrix}$$

Finally, by combining all three matrices, the Combined Effect Quantity Dependent Data Matrix (CEQD-Matrix) is generated, which provides the Cumulative effect of all these entries. This yields the CEQD-Matrix as well as the CEQD Row matrix:

Obtained CEQD matrix obtained row sum matrix

$$\begin{bmatrix} 3 & 2 & 3 & 0 \\ 0 & 3 & -1 & -3 \\ -3 & -2 & 1 & 3 \\ -1 & -3 & -2 & -3 \\ 3 & -1 & -3 & -1 \\ 2 & 1 & 0 & -2 \\ -2 & -3 & -3 & 0 \\ -3 & 0 & 3 & 3 \end{bmatrix} = \begin{bmatrix} 8 \\ -1 \\ -1 \\ -9 \\ -2 \\ 1 \\ -8 \\ 3 \end{bmatrix}$$

5. Plotting graphs with different values of $\alpha \in [0, 1]$ to Indicate the ant diversity

Using the technique of fuzzy matrices, the depicted graphs reflect the dominant group of Ants in sampling sites by altering $\alpha \in [0, 1]$.

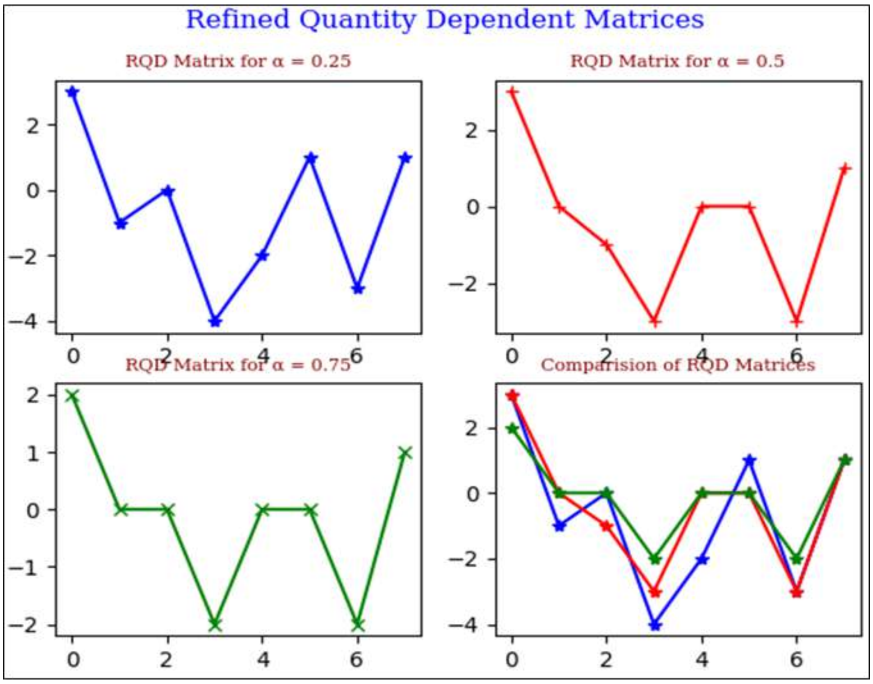

Fig 1: The maximum Ant diversity is depicted graphically for $\alpha = 0.25, 0.5, 0.75$ using Python

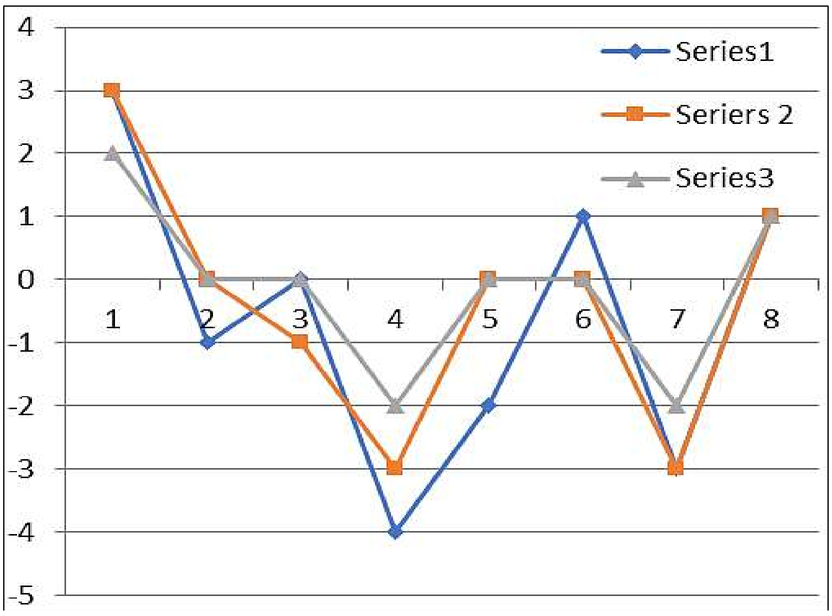

Fig 2: The maximum Ant diversity is depicted graphically for $\alpha = 0.25, 0.5, 0.75$ using excel

6. Plotting graph for the CEQD to depicting ant diversity

Combining Distinct Refined Quantity Dependent Data Matrices by altering $\alpha \in [0, 1]$ yields a, which represents the cumulative impact of all the entries. The combined effect quantity dependent data matrix is essential in showing the combine effect of all produced RQD matrices for various values of $\alpha = 0.25, 0.5$ and 0.75.

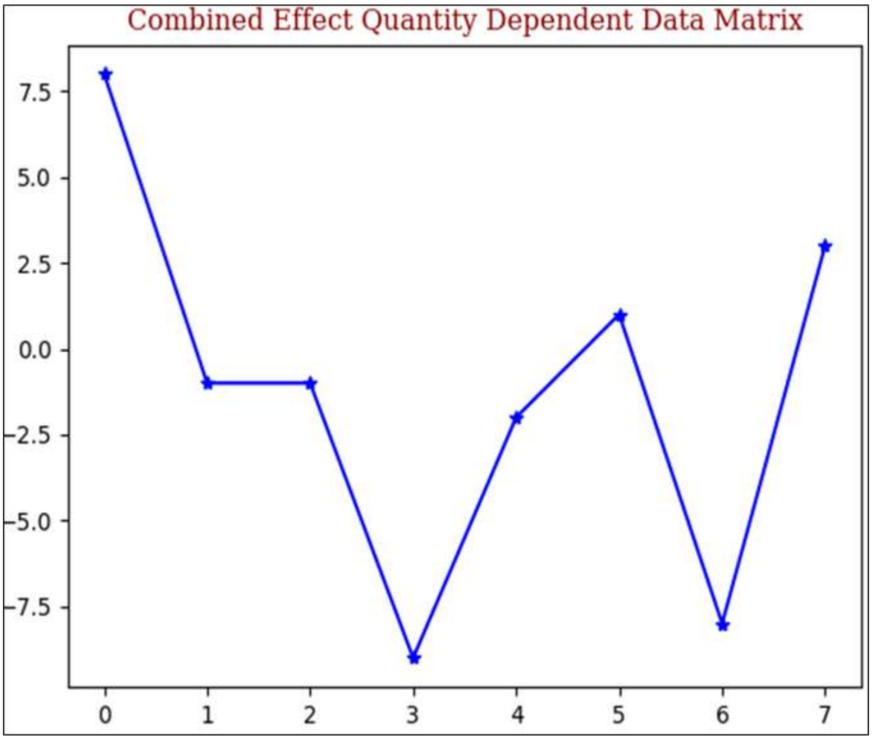

Fig 3: The maximum Ant diversity is depicted graphically for CEQDM using Python

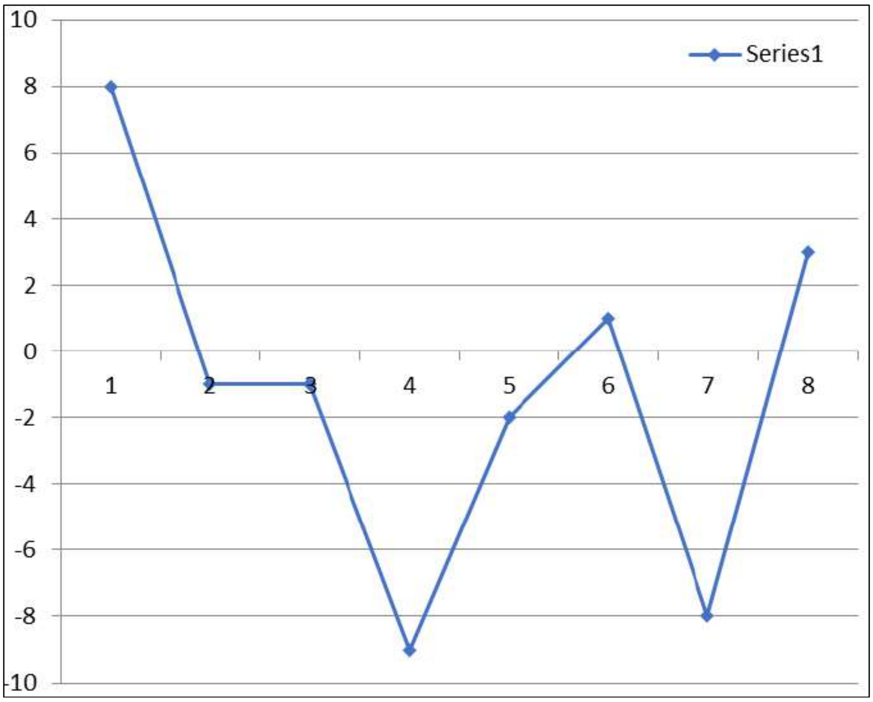

Fig 4: The maximum Ant diversity is depicted graphically for CEQDM using excel

5. Conclusion

From the above results, we depicted fuzzy graphs for different values of RQDM α = 0.25, 0.5, and 0.75 levels on the ant diversity. We concluded that, α = 0.75 level, the cooperation, landscape usage, diversity and distribution between the *Tetraponera*, *Myrmicaria brunnea* and *Oecophylla smaragdina* species were high. The medium level at α = 0.5 level the ants *Paratrechina longicornis*, *Camponotus mitis*, and *Solenopsis geminate* followed by the low-level assemblage at α = 0.25 *Camponotus barbatus* and *Trichomyrmex glaber*. The Combined Effect Quantity Dependent Data Matrix (CEQDDM) showed that among the eight species, *Tetraponera rufonigra* predominantly occupied the all sites, followed by *Oecophylla smaragdina*. This fuzzy combined effect time quantity dependent data matrix predicts the dominant species or rare species in the study sites and also the anthropogenic disturbance to disturb the faunal diversity and distribution.

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References

1. Bruhl CA, Gunsalam G, Linsenmair KE. Stratification of ants (Hymenoptera, Formicidae) in a primary rain forest in Sabah, Borneo, Journal of Tropical Ecology; c1998. p. 285-297.
2. Quicke DL. Hymenoptera: Ants, bees, wasps. In Encyclopedia of insects. Academic Press; c2009. p. 473-484.
3. Juan A Balbuena, Clara Monlleó-Borrull, Cristina Llopis-Belenguer, Isabel Blasco-Costa, Volodimir L Sarabeev, Serge Morand. Fuzzy quantification of common and rare species in ecological communities (Fuzzy Q). Methods in Ecology and Evolution. 2021;12(6):959-1143.
4. De Cáceres M, Font X, Oliva F. The management of vegetation classifications with fuzzy clustering, Journal of Vegetation Science. 2010;21:1138-1151. https://doi.org/10.1111/j.1654-1103.2010.01211.x
5. Dario F, Vincent L, Thomas B. On the Art of Classification in Spatial Ecology: Fuzziness as an Alternative for Mapping Uncertainty, Frontiers in Ecology and Evolution. 2018;6:1-5.
6. Bagnaro A, Baltar F, Brownstein G. Reducing the arbitrary: fuzzy detection of microbial ecotones and ecosystems-focus on the pelagic environment, Environmental Microbiome. 2020;15(16):1-14. https://doi.org/10.1186/s40793-020-00363-w.
7. Bandelj V, Solidoro C, Curiel D, Cossarini G, Melaku Canu D, Rismondo A. Fuzziness and Heterogeneity of Benthic Meta communities in a Complex Transitional System, PLoS One. 2012;7(12):1-15.
8. https://doi.org/10.1371/journal.pone.0052395.
9. Kosko B. Fuzzy cognitive maps, International Journal of Man-Machine Studies. 1986;24(1):65-75. https://doi.org/10.1016/S0020-7373(86)80040-2
10. Vasantha Kandasamy WB. Florentin Smarandache and Ilanthenral, Elementary Fuzzy Matrix Theory and Fuzzy Models for Social Scientists, Printed in United States of America; c2007.
11. Devadoss V, Anand CJ. Dimensions of Personality of Women in Chennai using CETD Matrix, International Journal of Computer Applications. 2012;50(5):10-17.
12. Narayanamoorthy S. Application of Fuzzy CETD matrix Technique to estimate the maximum age group of Silk weavers as bonded laborers, International Journal of Applied Mathematics & Mechanics. 2012;8(2):89-98.
13. Narayanamoorthy S, Smitha MV, Sivakamasundari K. Fuzzy CETD Matrix to Estimate the Maximum Age Group Victims Pesticide Endosulfan Problems Faced in Kerala, International Journal of Mathematics and Computer Applications Research. 2013;3:227-232.
14. Kokila R. Fuzzy Matrix Analysis of Students Information Gathering Attitude, International Journal of Science and Research. 2015;4(11):1338-1342.
15. Arockiaraj J, Murali N. Fuzzy Matrix Analysis of Seasonal Fishing in Cuddalore District, International Journal of Mathematics and its Applications. 2016;4(4):207-213.
16. Husain I, Ali A. Fuzzy Matrix Approach to Study the Maximum Age Group of Stressed Students Studying in Higher Education, International Journal on Emerging Technologies. 2021;12(1): 31-35.
17. Radhika, Missier SP, Jackson S. Fuzzy Matrix Analysis in Aqua Culture, International Journal of Mathematics and its Applications. 2017;5(4):999-1005.
18. Radhika K, Anbalagan Alexander, Mariyappan S. Risk Factor of Breast Cancer using CETD Matrix-An Analysis, International Journal of Applied Engineering Research. 2019;14(4):67-73.
19. Azhagu Raj R, Sathish R, Prakasam A, Krishnamoorthy D, Balachandar M. Diversity and distribution of Ant species (Hymenoptera: Formicidae), in Pachaiyappa's College, Kanchipuram, Tamil Nadu, India. Journal of Entomology and Zoology Studies. 2017;5(1):459-464.