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Rainfall as Correlate of Species Richness of Indian Ants (Hymenoptera: Formicidae)

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Abstract: The rainfall as a key predictor for the spatial distribution of any terrestrial species and this study aimed to understand the effect of rainfall on the subfamilies of ants of India. The simple and multiple linear regression models was used to understand the effect of annual and seasonal rainfall independently and collectively on species richness of ant subfamilies. The pre-monsoon and winter rainfall independently had significant effect while monsoon and post-monsoon rainfall independently had no significant predictor effect on species richness of subfamilies of ants. However, the combining seasonal rainfall for multiple linear regressions indicated that monsoon, post-monsoon, winter and pre-monsoon rainfall have significant predictor effect on five ant subfamilies.

Keywords: Ant, Species richness, Linear model, Rainfall, India

Ants are eusocial insects belong to the family Formicidae under order Hymenoptera. With more than 13000 described species worldwide, ants are one of the most abundant groups of insects in many ecosystems, play a considerable role in shaping ecosystems and participate in numerous and diverse interactions with other organisms (Guénard et al 2012). Global studies found that the Oriental region and tropical Asia have highest generic and endemic diversity of ants (Guénard et al. 2012). From India, 828 species and subspecies belonging to 100 genera are reported of which the state of West Bengal has the highest number of species (382) representing 65 genera followed by state of Sikkim with 276 species representing 69 genera (Bharti et al 2016, Fig. 1). For a large majority of taxa, including invertebrates, species richness increases with precipitation at macroecological scales (Delsinne et al. 2010). It is a general prediction that species diversity of insect increases with the increase of rainfall but, huge variation in the life history and survival strategies in the insects does not follow this trend always. In case of ants, usually rainfall has no or negative influence on diversity (Dunn et al 2009, 2010, Delsinne et al 2010).

It is a common assumption that correlative relationship model between environment and diversity wield in a similar manner across the globe but for insects these models remain largely unexplored (Jenkins et al 2011). If evolutionary history has shaped a fauna such that it responds differently to the environment in one region than fauna in other regions, then a region-specific model may be needed (Ricklefs 2007). Understanding the influence of precipitation on the diversity and composition of ant assemblages at a large geographical scale is difficult (Delsinne et al 2010). In the present work, we performed simple and multiple linear modelling to assess the effect of rainfall on species richness of ant subfamilies in India.

MATERIAL AND METHODS

The 30 administrative areas of India were selected for the present study (Fig. 1). State wise 2016 rainfall data was obtained from Kaur and Purohit (2016). For analysis considered rainfall data (in mm) of 4 seasons namely winter (January and February), pre-monsoon (March, April and May), monsoon (June, July, August and September) and post-monsoon (October, November and December) as well as total annual rainfall. The distribution data of 10 subfamilies of ants (Amblyoponinae, Dolichoderinae, Dorylinae, Ectatomminae, Formicinae, Leptanillinae, Myrmicinae, Ponerinae, Proceratiinae and Pseudomyrmecinae) of India was collected from Bharti et al (2016) and Maqbool (2018).

The two factor analysis was performed using SPSS software (v20) to observe significant difference of species richness of ant subfamilies present between the administrative areas as well as between the subfamilies. The 5 predictor variables (annual rainfall, winter rainfall, pre-monsoon rainfall, monsoon rainfall and post-monsoon rainfall) and species richness of ant subfamilies as response variables for simple linear regression modelling were considered. The 11 possible combinations of predictors (monsoon + post-monsoon, pre-monsoon + monsoon, winter + monsoon, winter + post-monsoon, winter + pre-monsoon , pre-monsoon + post-monsoon, pre-monsoon + monsoon + post-monsoon, winter + monsoon + post-monsoon, winter + pre-monsoon + monsoon, winter + pre-monsoon + post-monsoon and winter + pre-monsoon + monsoon + post-monsoon) was considered for multiple linear modelling with response variables (species richness of 10 subfamilies and total species richness of all subfamilies). For the families with more than one model, calculated corrected Akaike Information Criterion (AIC) values to get the best predictor model.

RESULTS AND DISCUSSION

There was significant difference in species richness between different ant subfamilies and also significant difference present in species richness of ant subfamilies in different administrative areas of India. With total annual rainfall, only subfamily Ectatomminae has significant and positive simple linear relationship (Table 1, Fig. 2). Winter rainfall has great effect on species richness of subfamilies of ants (Table 2, Fig. 2). Out of 10 subfamilies, species richness of 6 subfamilies namely Amblyoponinae, Dolichoderinae, Dorylinae, Ectatomminae, Formicinae and Myrmicinae has significant and positive simple linear relationship with winter rainfall. Collectively, total species richness of all the subfamilies also has significant and positive simple linear relationship with winter rainfall. Species richness of 6 subfamilies namely Dolichoderinae, Ectatomminae and Ponerinae has significant and positive simple linear relationship with pre-monsoon rainfall (Table 3, Fig. 2). Collectively, total species richness of all the subfamilies also has significant and positive simple linear relationship with

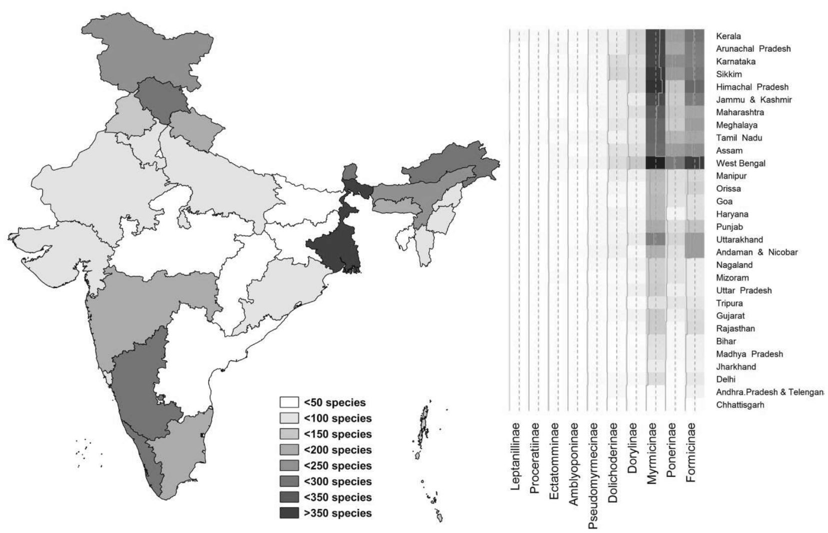

Fig. 1. Species richness of 10 ant subfamilies in different states and union territories of India

Table 1. Relationship between annual total rainfall and species richness of subfamilies of ants

	β	R^2	SE	$F_{1,28}$	p
All subfamily	0.026	0.0460	0.023	1.349	0.255
Amblyoponinae	0.0002	0.027	0.0003	0.77	0.388
Dolichoderinae	0.002	0.081	0.001	2.477	0.127
Dorylinae	0.001	0.028	0.002	0.821	0.373
Ectatomminae	0.0008	0.331	0.0002	13.84	0.0009
Formicinae	0.006	0.041	0.006	1.196	0.283
Leptanillinae	-2.176×10^{-5}	0.0009	1.375×10^{-4}	0.025	0.875
Myrmicinae	0.008	0.028	0.01	0.796	0.38
Ponerinae	0.006	0.078	0.004	2.362	0.136
Proceratiinae	0.0001	0.028	0.0002	0.804	0.378
Pseudomyrmecinae	0.0005	0.057	0.0004	1.684	0.205

The p value in boldface type signifies the linear relationship (α = 0.05) pre-monsoon rainfall. Monson and post-monsoon rainfall has no effect on species richness of subfamilies of ants (Table 4 and 5).

Out of possible 121 multiple linear models (11 combinations of predictors and 11 response variables) only 15 models were be significant (Table 6, Fig. 3). Unlike simple linear regression models, monsoon and post-monsoon rainfall have significant predictor effect on 7 and 8 multiple linear models, respectively. Winter and pre-monsoon rainfall have significant predictor effect on 12 and 9 multiple linear models. Species richness of only 4 families namely Dolichoderinae, Ectatomminae, Formicinae and Myrmicinae as well as total species richness of the all subfamilies showed significant response to the multiple linear regressions. Rest five subfamilies (Amblyoponinae, Dorylinae, Leptanillinae, Ponerinae, Proceratiinae and Pseudomyrmecinae) have no significant response to the multiple linear regressions.

Understanding the factors that drive species richness and composition at multiple scales is of crucial importance for conservation (Pacheco et al 2012). The works by earlier

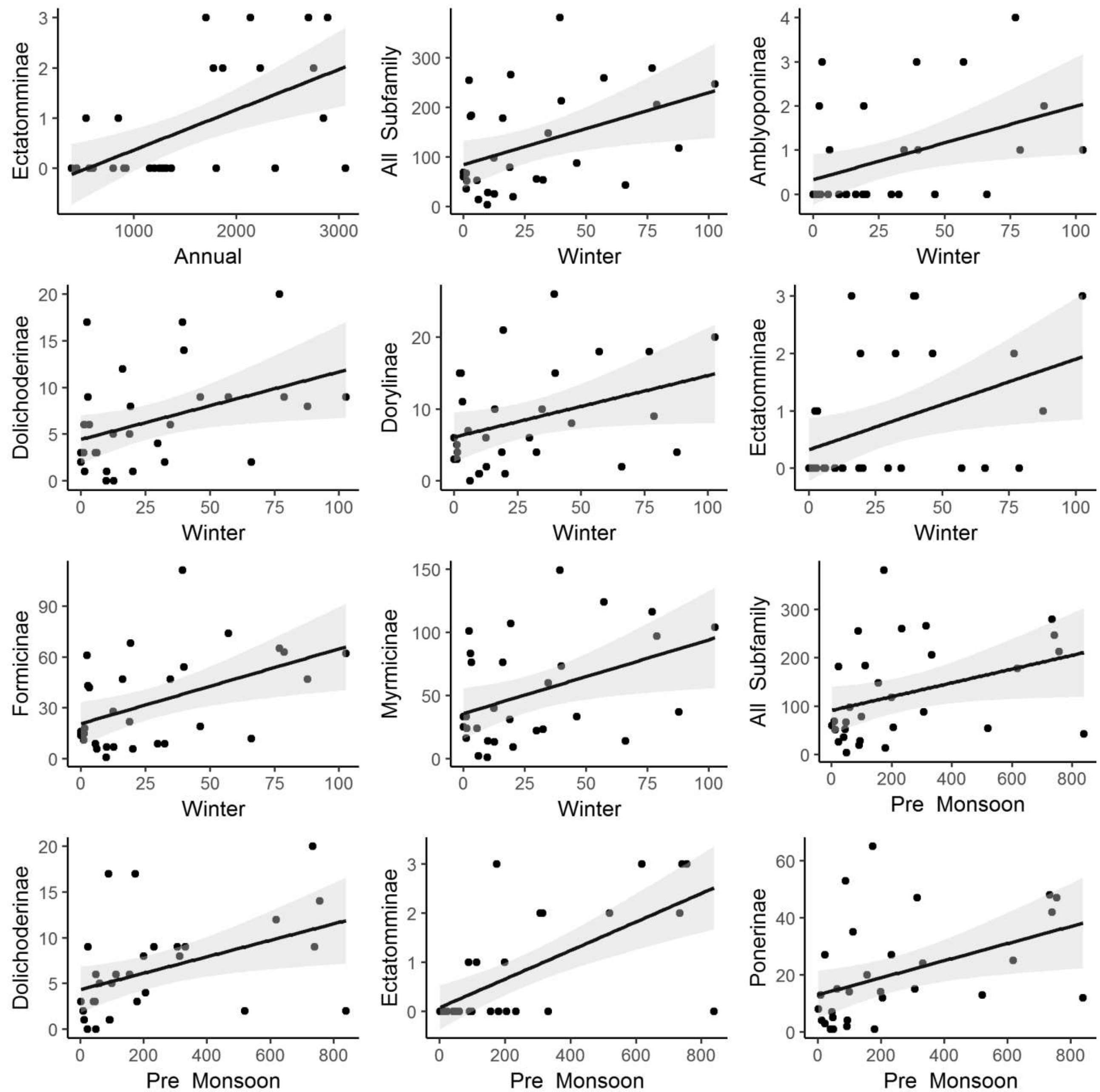

Fig. 2. Significant simple linear regression models between rainfall (in mm) (on x axis) and species richness (on y axis) of subfamily of ants ($p < 0.05$)

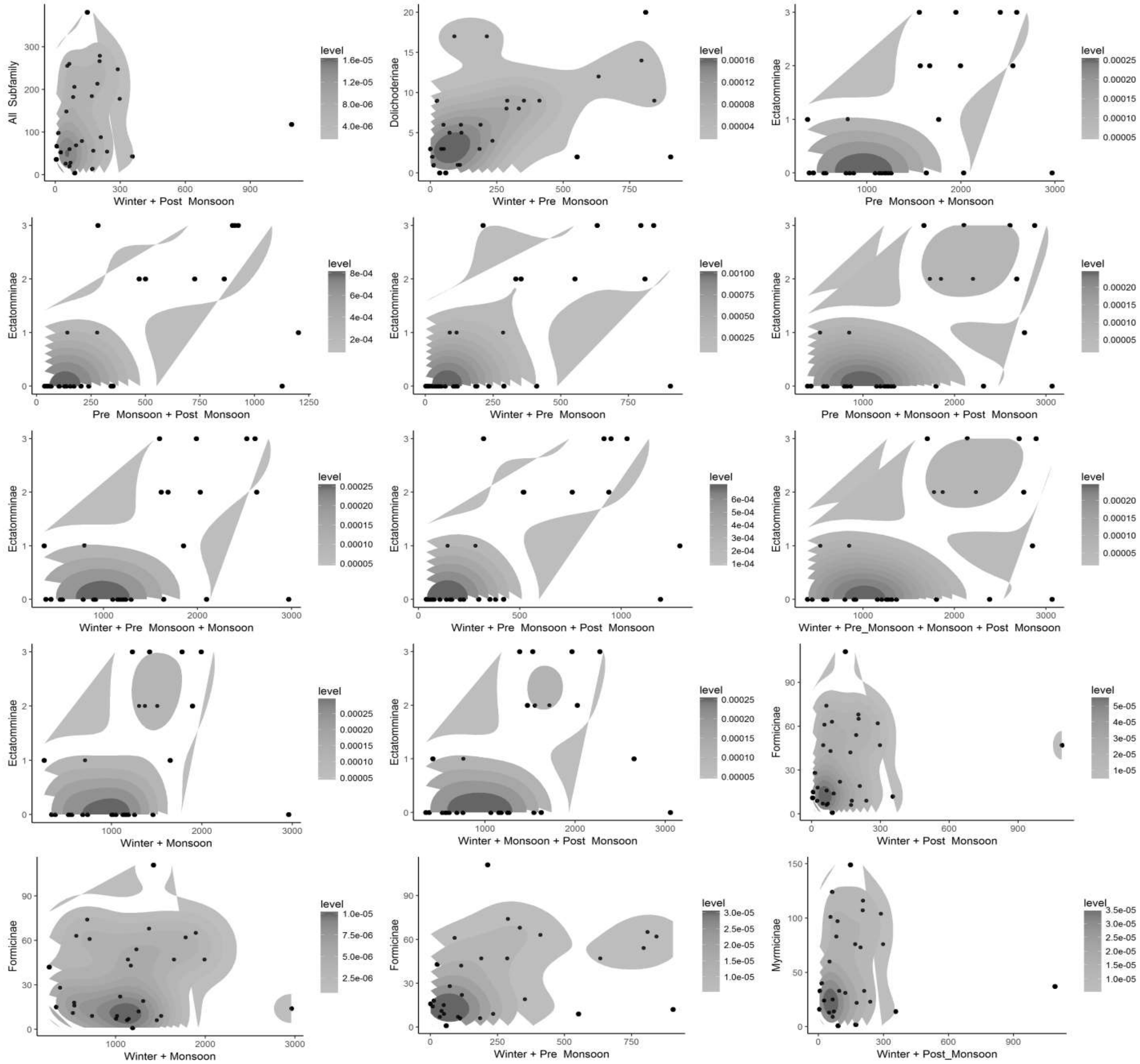

Fig. 3. Significant multiple linear regression models between seasonal rainfalls (in mm) (on x axis) and species richness (on y axis) of subfamily of ants ($p < 0.05$)

Table 2. Relationship between winter rainfall and species richness of subfamilies of ants

	β	R^2	SE	$F_{1,28}$	p
All subfamily	1.449	0.182	0.581	6.23	0.019
Amblyoponinae	0.017	0.172	0.007	5.807	0.023
Dolichoderinae	0.072	0.161	0.031	5.354	0.028
Dorylinae	0.086	0.131	0.086	4.208	0.049
Ectatomminae	0.015770	0.168	0.007	5.638	0.025
Formicinae	0.441	0.225	0.155	8.104	0.008
Leptanillinae	-0.0008	0.002	0.004	0.047	0.829
Myrmicinae	0.583	0.171	0.243	5.782	0.023
Ponerinae	0.2187	0.13	0.1071	4.167	0.051
Proceratiinae	0.004	0.034	0.004	0.978	0.331
Pseudomyrmecinae	0.014	0.055	0.011	1.637	0.211

The p value in boldface type signifies the linear relationship ($\alpha = 0.05$)

Table 3. Relationship between pre-monsoon total rainfall and species richness of subfamilies of ants

	β	R^2	SE	$F_{1,28}$	p
All subfamily	0.142	0.133	0.068	4.307	0.047
Amblyoponinae	0.001	0.060	0.0008	1.801	0.190
Dolichoderinae	0.009	0.189	0.004	6.536	0.016
Dorylinae	0.009	0.119	0.005	3.781	0.062
Ectatomminae	0.002	0.433	0.0006	21.35	7.82×10^{-05}
Formicinae	0.034	0.103	0.019	3.222	0.083
Leptanillinae	0.00005	0.0006	0.0004	0.016	0.902
Myrmicinae	0.053	0.109	0.029	3.418	0.075
Ponerinae	0.03	0.186	0.012	6.388	0.017
Proceratiinae	0.0009	0.128	0.0005	4.096	0.053
Pseudomyrmecinae	0.001	0.035	0.001	1.024	0.320

The p value in boldface type signifies the linear relationship (α = 0.05)

Table 4. Relationship between monsoon rainfall and species richness of subfamilies of ants

	β	R^2	SE	$F_{1,28}$	p
All subfamily	0.018	0.011	0.033	0.308	0.583
Amblyoponinae	7.662×10^{-5}	0.001	3.918×10^{-4}	0.038	0.8464
Dolichoderinae	0.001	0.022	0.002	0.639	0.4308
Dorylinae	0.0009	0.007	0.002	0.188	0.668
Ectatomminae	0.0008	0.165	0.0003	5.526	0.026
Formicinae	0.004	0.007	0.009	0.187	0.669
Leptanillinae	-6.124×10^{-5}	0.003	1.954×10^{-4}	0.098	0.756
Myrmicinae	0.006	0.006	0.014	0.162	0.691
Ponerinae	0.005	0.027	0.006	0.784	0.384
Proceratiinae	8.391×10^{-5}	0.005	2.247×10^{-4}	0.14	0.712
Pseudomyrmecinae	0.0005	0.024	0.0006	0.698	0.411

The p value in boldface type signifies the linear relationship (α = 0.05)

Table 5. Relationship between post-monsoon rainfall and species richness of subfamilies of ants

	β	R^2	SE	$F_{1,28}$	p
All subfamily	0.025	0.002	0.103	0.057	0.813
Amblyoponinae	0.001	0.04	0.001	1.152	0.292
Dolichoderinae	0.004	0.015	0.005	0.438	0.514
Dorylinae	-0.002	0.002	0.007	0.065	0.800
Ectatomminae	0.002	0.088	0.001	2.701	0.112
Formicinae	0.017	0.014	0.028	0.389	0.538
Leptanillinae	8.133×10^{-5}	0.0006	6.093×10^{-4}	0.018	0.895
Myrmicinae	-0.006	0.0008	0.043	0.022	0.884
Ponerinae	0.006	0.004	0.018	0.102	0.752
Proceratiinae	-3.347×10^{-5}	8.133e-05	7.014×10^{-4}	0.002	0.962
Pseudomyrmecinae	0.006	0.072	0.002	2.181	0.151

The p value in boldface type signifies the linear relationship (α = 0.05)

Table 6. Significant multiple linear regression model between species richness of ant subfamilies (Response variables) and seasonal rainfall (Predictor variables) ($p < 0.05$)

Subfamily					Predictors							
					Winter rainfall		Pre-monsoon rainfall		Monsoon rainfall		Post-monsoon rainfall	
	AICc	R^2	F	p	β	SE	β	SE	β	SE	β	SE
All subfamily		0.212	$F_{2,27}$ = 3.644	0.03	1.763	0.656					-0.107	0.105
Dolichoderinae		0.209	$F_{2,27}$ = 3.565	0.042	0.035	0.043	0.006	0.005				
Ectatomminae	82.587	0.465	$F_{2,27}$ = 11.71	0.0002			0.003	0.0007	0.0004	0.0003		
Ectatomminae	83.665	0.445	$F_{2,27}$= 10.82	0.0004			0.003	0.0007			0.0007	0.0009
Ectatomminae	84.141	0.436	$F_{2,27}$= 10.44	0.0004	-0.003	0.008	0.003	0.0009				
Ectatomminae	85.269	0.468	$F_{3,26}$= 7.636	0.0008			0.003	0.0007	0.0003	0.0003	0.0004	0.001
Ectatomminae	85.315	0.468	$F_{3,26}$= 7.611	0.0008	-0.003	0.008	0.003	0.0009	0.0003	0.0003		
Ectatomminae	85.909	0.457	$F_{3,26}$= 7.291	0.001	-0.006	0.008	0.003	0.0009			0.001	0.001
Ectatomminae	87.978	0.476	$F_{4,25}$= 5.681	0.002	-0.005	0.008	0.003	0.0009	0.0003	0.0003	0.0007	0.001
Ectatomminae	91.948	0.268	$F_{2,26}$= 4.953	0.015	0.013	0.007			0.0006	0.0003		
Ectatomminae	94.816	0.269	$F_{3,26}$= 3.192	0.04	0.012	0.007			0.0006	0.0004	0.0002	0.001
Formicinae	284.187	0.238	$F_{2,27}$= 4.227	0.025	0.499	0.177					-0.019	0.028
Formicinae	284.691	0.225	$F_{2,27}$= 3.931	0.032	0.448	0.162			-0.002	0.008		
Formicinae	284.731	0.224	$F_{2,27}$= 3.908	0.032	0.446	0.217	-0.0008	0.025				
Myrmicinae		0.234	$F_{2,27}$= 4.121	0.027	0.77	0.269					-0.064	0.04

scientist showed lack of meaningful relationships between ant diversity and precipitation (Morton and Davidson 1988, Medel 1995, Pfeiffer et al 2003, Dunn et al 2009, Dunn et al 2010, Delaine et al 2010). Present work has similitude with those works as in general, annual rainfall has no significant effect on the species richness of subfamilies of ants. But seasonal rainfall has significant effect on the species richness of different subfamilies, both independently as well as in linear combination. Different ant families have different life history and survival strategies. The variation in the effect of rainfall to the species richness of ant subfamilies may be results from this variation of life history and survival strategies.

CONCLUSION

The total annual rainfall has no effect on the ant subfamilies other than Ectatomminae but seasonal rainfall has a major impact. The monsoon and post-monsoon rainfall has no effect on any of the ant subfamilies. The winter and pre-monsoon rainfall have major impact on the ant subfamilies. Thus, seasonal variation in rainfall can shape the ant community of a region. Any change in rainfall pattern, especially due to climate change, can be devastating to ant communities. Further studies should be conducted to find out the optimal ecological correlates of Indian ant species richness in different habitats so that appropriate conservation actions can be planned and implemented for sustainable management of natural resources.

REFERENCES

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

Delsinne T, Roisin Y, Herbauts J and Leponce M 2010. Ant diversity along a wide rainfall gradient in the Paraguayan dry Chaco. *Journal of Arid Environments* **74**(10): 1149-1155.

Dunn R, Agosti D, Andersen AN, Arnan X, Bruhl CA, Cerda X, Ellison AM, Fisher BL, Fitzpatrick MC, Gibb H and Gotelli NJ 2009. Climatic drivers of hemispheric asymmetry in global patterns of ant species richness. *Ecology Letters* **12**(4): 324-333.

Dunn RR, Guénard B, Weiser MD and Sanders NJ 2010. *Geographic gradients*. In: Lach L, Parr CL, Abbott KL (Eds.), *Ant Ecology.* Oxford University Press, New York, p 38-58

Guénard B, Weiser MD and Dunn RR 2012. Global models of ant diversity suggest regions where new discoveries are most likely are under disproportionate deforestation threat. *Proceedings of the National Academy of Sciences* **109**(19): 7368-7373

Jenkins CN, Sanders NJ, Andersen AN, Arnan X, Brühl CA, Cerda X, Ellison AM, Fisher BL, Fitzpatrick MC, Gotelli NJ and Gove AD 2011. Global diversity in light of climate change: the case of ants. *Diversity and Distributions* **17**(4): 652-662

Maqbool A, Akbar SA and Wachkoo AA 2018. First record of the genus Ficobracon (Hymenoptera: Braconidae) from India, with description of new species. *Zootaxa* **4379**(3): 421-428.

Medel RG 1995. Convergence and historical effects in harvester ant assemblages of Australia, North America, and South America. *Biological Journal of the Linnean Society* **55**(1): 29-44

Morton SR and Davidson DW 1988. Comparative structure of harvester ant communities in arid Australia and North America.

Ecological Monographs **58**(1): 19-38

Pacheco R and Vasconcelos HL 2012. Habitat diversity enhances ant diversity in a naturally heterogeneous Brazilian landscape. *Biodiversity and Conservation* **21**(3): 797-809

Pfeiffer M, Chimedregzen L and Ulykpan K 2003. Community organization and species richness of ants (Hymenoptera/Formicidae) in Mongolia along an ecological gradient from steppe to Gobi Desert. *Journal of Biogeography* **30**(12): 1921-1935

Ricklef RE 2007. History and diversity: explorations at the intersection of ecology and evolution. *The American Naturalist* **170**(S2): S56-S70

Singh AP, Chandra A, De K, Uniyal VP and Sathyakumar S 2022. Decreasing potential suitable habitat of bumble bees in the Great Himalayan National Park Conservation area. *Oriental Insects* **57**(1): 36-53

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