

A STUDY ON THE ANT DIVERSITY (HYMENOPTERA: FORMICIDAE) OF  
PERIYAR TIGER RESERVE IN SOUTH WESTERN GHATS

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ABSTRACT

Ants represent a unique focal group, due to their ability to navigate across all trophic levels, along with their sensitivity to any changes in the environment. The present study aims to determine the species composition of ants across varying vegetation types in Periyar Tiger Reserve of Southern Western Ghats. Thirty one (31) species of ants belonging to 14 genus and 4 subfamilies were collected from different habitats of the reserve. This study emphasizes the dominance exhibited by the subfamily *Formicinae* within the ant communities, due to their ability to adapt to different niches. *Harpegnathos saltator*, a species endemic to Western Ghats and *Paratrechina longicornis* listed in the IUCN red list were collected from the habitat. Out of the total 31 species collected from the five different habitats of the study area, 24 species of ants were found in the semi-evergreen habitat making it the most species rich habitat.

**Key words :** Ants, Periyar Tiger Reserve, Western Ghats, *Paratrechina longicornis*

Introduction

Inclusion of ground-dwelling arthropods in biodiversity inventories and environmental assessment surveys has increased in the recent past (Oliver and Beattie, 1996). Ants (Hymenoptera : Formicidae) have numerous advantages over other arthropods in studies of species diversity. They occur throughout the world, easily collected, taxonomically well known and constitute an important fraction of the animal biomass in terrestrial ecosystems (Fittkau and Klinge, 1973; Hölldobler and Wilson, 1990). They also respond to stress on a much finer scale than do vertebrates (Andersen, 1997). Moreover, ants perform major ecological functions (Hölldobler and Wilson, 1990). As important invertebrate predators, scavengers, seed dispersers and competitors; ground-dwelling ants exert a strong influence on the arthropod community in tropical rain forests (Hölldobler and Wilson, 1990). In addition, they play key roles in the movement of soil, transfer of organic materials, better aeration (Agosti *et al.*, 2000). But there are difficulties associated with the sampling of ants as they are locally very numerous, with a wide range of mobility requiring enormous sampling efforts where complete enumeration is not possible as fauna may shift in relation to microclimate/environmental factors (Bestelmeyer *et al.*, 2000; Bruhl *et al.*, 1999; Elmes and Wardlaw, 1982).

Ants include about 1% of all described insect species, with 2,136 subspecies and 12,116 extant species

in 298 genera coming under 21 subfamilies all over the world. In India the ant fauna is representative of this diversity with 660 species from 87 genera and includes 12 of the 21 known subfamilies (Aenictinae, Amblyoponinae, Cerapachyinae, Dolichoderinae, Dorylinae, Ectatomminae, Formicinae, Leptanillinae, Myrmicinae, Ponerinae, Proceratiinae, Pseudomyrmecinae) (Bharti, 2012).

Information on biogeographical variation in species richness and endemic richness is critical in understanding and conservation of biological diversity, and to develop rigorous conservation plans for a region (Fisher and Robertson, 2002; Grytnes and Vetaas, 2002; Fu *et al.*, 2004, 2006). Most research to date has focused on providing vertebrate data for conservation assessment and for many groups of invertebrates. We lack even basic information in tropical ecosystems (Fisher and Robertson, 2002). This is particularly true for the ant fauna of subtropical Western Ghats forests, a recognized global hot spot of biodiversity in India (Myers *et al.*, 2000; Myers, 2003; Bossuyt *et al.*, 2004). Though the floral and vertebrate faunal found in the Periyar Tiger Reserve region are well documented, little is known of the invertebrate distributional pattern of these forests. Till date, no scientific studies of ant fauna have been conducted in this region.

Objective of the study is to record the diversity of ants in the Vallakadavu range and to assess the habitat preference of ant species in the different vegetation

Thirty one (31) species of ants belonging to 14 genera under 4 subfamilies were found to inhabit varying vegetation type of Periyar Tiger Reserve of southern Western Ghats.

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type, of the Periyar Tiger Reserve.

## Material and Methods

### Study area

Periyar Tiger Reserve (PTR) is one of the most prestigious tiger reserve in India, in the south eastern part of Kerala state, along with its adjacent forested areas in Ranni, Konni and Achenkovil Forest Divisions. It remains one of the largest contiguous blocks of tropical evergreen forest and an important habitat for many life forms. The mosaic of habitats in PTR, especially in Thekkady and Vallakadavu ranges, support a repository of rare, endemic and endangered flora and fauna with an area: 925 km<sup>2</sup> (Latitude: 9°17'56.04" - 9°37'0.2" N and Longitude: 76°56'12.12" - 77°25'5.52"E). The reserve is divided into two functional divisions, Periyar East and West. Periyar East is the larger division with an area of 707 km<sup>2</sup>. This region is divided into 3 ranges- Thekkady, Periyar and Vallakadavu. Study is conducted at Vallakadavu Range of the Periyar East division (Fig.1). Terrain is undulating with lofty peaks with an average elevation of 1200 meters. The temperature ranges from 15°C to 31°C. The annual rainfall ranges from 2000 mm to 3000 mm. Two-thirds of the rainfall occurs during the south west monsoon from June to September. The northeast monsoon impacts from October to December. The study is done during the post monsoon month of January. The predominant vegetation type in Vallakadavu range is evergreen forests, in addition to semi-evergreen and moist deciduous forests, grass lands and eucalyptus plantations. Out of 3800 estimated species of flowering plants in Kerala, 1980 have been

reported in PTR, of which three are endemic to PTR. It also harbours 63 species of mammals (7 endemic to Western Ghats (WG)), 323 species of birds (14 endemic to WG), 45 species of reptiles (18 endemic to WG), 54 species of fishes (7 endemic to PTR), 27 species of amphibians (10 endemic to WG), 160 species of butterflies including 20 WG endemic species (Kerala Forest Department, 2003; Radhakrishnan and Kurup, 2010). Even though, a number of studies have been conducted on the status, ecology and behaviour of many large and charismatic animals like tiger, elephant and other vertebrates in PTR, taxonomic studies and documentation of invertebrates still remain extremely scanty (Palot *et al.*, 1997; Joseph *et al.*, 1997). With the announcement of U.N.- India Biodiversity Governance award for best managed protected area in the country, further studies on documenting the biodiversity of this region will receive a boost.

### Methodology

Ants were collected from five different vegetations viz., evergreen, semi evergreen, deciduous, grassland and riparian vegetation with pitfall traps, Quadrate method and visual collections during the post monsoon month of January.

**Pitfall trap :** Each plot was divided into 30 quadrates. A plastic container (8 cm dia. × 12 cm height) was placed in each hole with the lip of the trap level with the soil surface. 90% ethyl alcohol with 3 drops of glycerin was used for a pitfall trap. Samples were collected after 24 hours.

**Quadrate Method :** 10 X 10 quadrates were placed in the

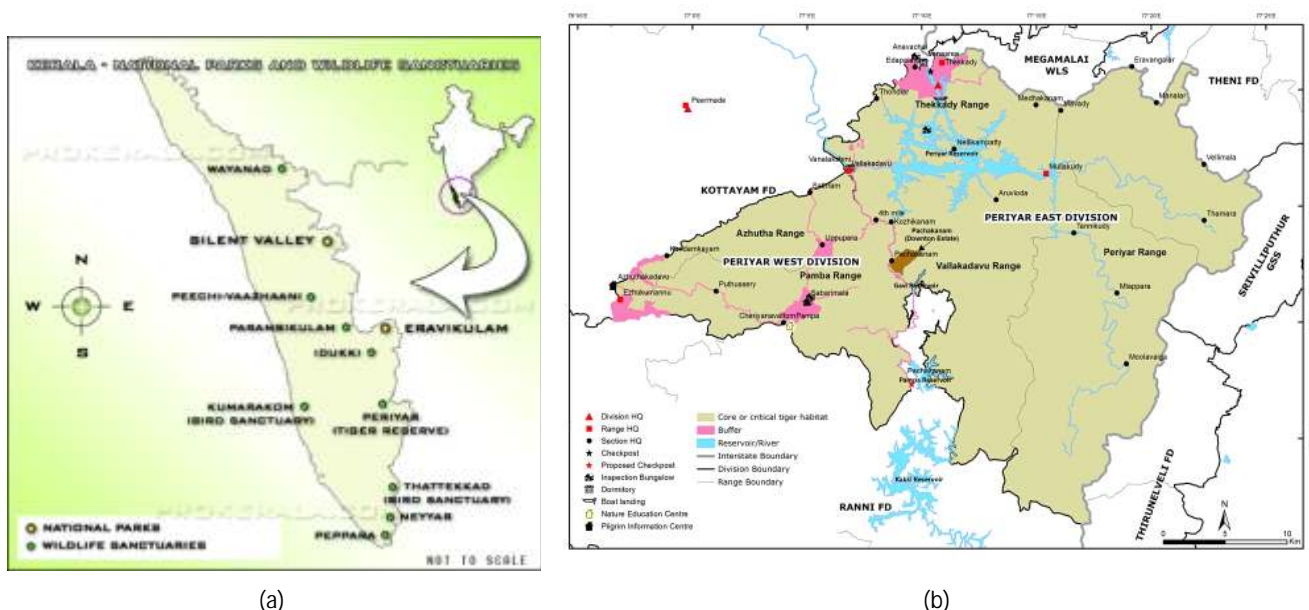


Fig. 1 : (a) Map of India showing the location of Kerala with location of National parks and Wild life Sanctuaries (b) The study habitat in Periyar Tiger Reserve Region.

five different vegetation types. 25 quadrates were laid; 30 minutes were spent per day in each quadrate and collected the specimens in labelled bottles containing 70% ethanol.

A visual collection was done for a period of an hour, which involved sweep net method, checking in barks, rotting logs and on leaves. From all traps insects were sorted and ants were separated for identification and mounted after the technique of Bolton (1994). Thereafter genera were identified with Bolton's (1994) and Bingham's (1903) key and morphospecies were delineated based on external morphological characters using a microscope and the specimens have been kept at the Zoology museum of St. Xavier's College Aluva. We used occurrence data of ants in this study.

Data Analysis: Ant biodiversity in the Periyar Tiger Reserve was analysed using the following alpha diversity indices: number of species (S), Shannon's diversity index (H' using log e) and Simpson's dominance index (D'). They were calculated with PAST software Version 2.07.

## Results

Preliminary study of ant fauna of Periyar Tiger Reserve could collect 31 species of ants belonging to 14 genus and 4 subfamilies (Table 1). Of the ants collected, Formicinae was the most species rich subfamily (13 species) followed by Myrmicinae (10 species) and Ponerinae (7 species). Subfamily Pseudomyrmecinae had only one representative species. The three most species rich genera were *Camponotus* (7 species), *Leptogenys* (5 species) and *Polyrachis* (4 species). *Harpegnathos saltator*, a species endemic to Western Ghats and *Paratrechina longicornis* listed in the IUCN red list collected from the habitat stresses the need for further studies in the region to document and preserve the area. The behaviourally dominant group of ants, dominant dolichoderines were absent in the collections.

Ants collected from the six different forest habitats of the Periyar Tiger Reserve showed specific habitat preference with not all species being present in all the habitats. Out of the total 31 species collected from the five different habitats of the study area, 24 species of

Table 1 : Ant species collected from Periyar Tiger Reserve during the study period

Sl No.	Family	Subfamily	Genus	Species
1	Formicidae	Formicinae	<i>Camponotus</i>	<i>binghamii</i>
2	Formicidae	Formicinae	<i>Camponotus</i>	<i>rufoglaucus</i>
3	Formicidae	Formicinae	<i>Camponotus</i>	<i>barbatus</i>
4	Formicidae	Formicinae	<i>Camponotus</i>	<i>carin</i>
5	Formicidae	Formicinae	<i>Camponotus</i>	<i>compressus</i>
6	Formicidae	Formicinae	<i>Camponotus</i>	<i>angusticollis</i>
7	Formicidae	Formicinae	<i>Camponotus</i>	<i>parius</i>
8	Formicidae	Formicinae	<i>Polyrachis</i>	<i>pubescence</i>
9	Formicidae	Formicinae	<i>Polyrachis</i>	<i>exercita</i>
10	Formicidae	Formicinae	<i>Polyrachis</i>	<i>rastellata</i>
11	Formicidae	Formicinae	<i>Polyrachis</i>	<i>proxima</i>
12	Formicidae	Formicinae	<i>Oecophylla</i>	<i>smaragdina</i>
13	Formicidae	Formicinae	<i>Paratrechina</i>	<i>longicornis</i>
14	Formicidae	Ponerinae	<i>Harpegnathos</i>	<i>saltator</i>
15	Formicidae	Ponerinae	<i>Leptogenys</i>	<i>peuqueti</i>
16	Formicidae	Ponerinae	<i>Leptogenys</i>	<i>falcigera</i>
17	Formicidae	Ponerinae	<i>Leptogenys</i>	<i>hodgsoni</i>
18	Formicidae	Ponerinae	<i>Leptogenys</i>	<i>ocellifera</i>
19	Formicidae	Ponerinae	<i>Leptogenys</i>	<i>dentilobis</i>
20	Formicidae	Ponerinae	<i>Odontomachus</i>	<i>haematodus</i>
21	Formicidae	Myrmicinae	<i>Pheidologeton</i>	<i>affinis</i>
22	Formicidae	Myrmicinae	<i>Pheidologeton</i>	<i>diversus</i>
23	Formicidae	Myrmicinae	<i>Solenopsis</i>	<i>nitens</i>
24	Formicidae	Myrmicinae	<i>Tetramorium</i>	<i>yerburyi</i>
25	Formicidae	Myrmicinae	<i>Tetramorium</i>	<i>nursei</i>
26	Formicidae	Myrmicinae	<i>Myrmecina</i>	<i>striata</i>
27	Formicidae	Myrmicinae	<i>Myrmecina</i>	<i>sp</i>
28	Formicidae	Myrmicinae	<i>Crematogaster</i>	<i>wroughtoni</i>
29	Formicidae	Myrmicinae	<i>Crematogaster</i>	<i>buddhae</i>
30	Formicidae	Myrmicinae	<i>Carebara</i>	<i>sp</i>
31	Formicidae	Pseudomyrmecinae	<i>Tetraponera</i>	<i>rufonigra</i>

Table 2 : Ant species collected from five different habitats of the Periyar Tiger Reserve

Sl. No.	Species	Forest Type				
		Evergreen	Semievergreen	Deciduous	Grassland	Riparian
1	<i>Camponotus binghami</i>		*		*	*
2	<i>Camponotus rufoglaucus</i>		*	*	*	*
3	<i>Camponotus barbatus</i>	*	*		*	
4	<i>Camponotus carin</i>		*		*	*
5	<i>Camponotus compressus</i>		*	*	*	*
6	<i>Camponotus angusticollis</i>		*		*	*
7	<i>Camponotus parius</i>		*	*		
8	<i>Polyrhachis pubescence</i>					*
9	<i>Polyrhachis exercita</i>		*			
10	<i>Polyrhachis rastellata</i>		*	*		
11	<i>Polyrhachis Proxima</i>		*	*		*
12	<i>Oecophylla smaragdina</i>	*	*	*		
13	<i>Paratrechina longicornis</i>			*		
14	<i>Harpegnathos saltator</i>	*	*			
15	<i>Leptogenys peuqueti</i>			*		
16	<i>Leptogenys falcigera</i>	*	*			
17	<i>Leptogenys hodgsoni</i>		*		*	
18	<i>Leptogenys ocellifera</i>		*		*	
19	<i>Leptogenys dentilobis</i>		*			
20	<i>Odontomachus haematodus</i>		*			
21	<i>Pheidologeton affinis</i> Jerdon			*		
22	<i>Pheidologeton diversus</i>		*	*		
23	<i>Solenopsis nitens</i>		*			
24	<i>Tetramorium yerburyi</i>		*			
25	<i>Tetramorium nursei</i>		*			
26	<i>Myrmecina</i> sp			*		
27	<i>Myrmecina striata</i>			*		
28	<i>Crematogaster wroughtoni</i>	*	*	*		*
29	<i>Crematogaster buddhae</i>				*	
30	<i>Carebara</i> sp			*		
31	<i>Tetraponera rufonigra</i>		*			*

\*indicates presence of the species in the habitat

ants were found in the semi-evergreen habitat making it the most species rich habitat among the five vegetation types. All the four subfamilies collected from the Tiger Reserve were present in the semi-evergreen habitat. Evergreen habitat was the least speciose with only 5 ant species. *Camponotus* sp. and *Crematogaster* sp. were common to most of the habitats; *Pheidologeton affinis*, *Myrmicina* sp., *Carebara* sp., *Paratrechina longicornis*, *Leptogenys peuqueti* were specific to deciduous forest. *Crematogaster buddhae* and *Polyrhachis pubescence* were present only in the riparian region. *Harpegnathos saltator* a species which is endemic to Western Ghats was collected from evergreen and semi evergreen habitat of the study area. *Paratrechina longicornis* which was listed in the IUCN red list was collected from the deciduous habitat alone (Table 2).

Members of subfamily Formicinae was present in all the five habitats and was the dominant sub family in all habitats of the Periyar Tiger Reserve. Myrmicinae was the second most speciose subfamily with its members showing dominance in the deciduous and semi

evergreen habitats. Ponerines (true litter ants) were mainly concentrated in the semi-evergreen habitat of the Tiger Reserve. Pseudomyrmicinae with only one representative *Tetraponera rufonigra* showed its presence only in semi-evergreen and riparian vegetation.

Semievergreen habitat showed significantly high value for Shannon's diversity ( $H' = 3.135$ ;  $P < 0.05$  when compared with all other vegetations) followed by deciduous (2.64) and riparian habitats ( $H' = 2.30$ ). Evergreen habitat showed least value for Shannon's diversity index ( $H' = 1.61$ ). Simpson's dominance index indicated that the distribution of ant species in the semievergreen habitat was more even with less number of dominating species (Table 3).

#### Discussion

This study provides a glimpse of ant assemblages in a little-studied region of Periyar Tiger Reserve. 31 species of ants belonging to 14 genera and 4 subfamilies were collected within a short span of fifteen days. Number of ant species so far collected from Indian peninsula amounts to 660 species (Bharti, 2012). Results

Table 3: Alpha diversity indices for different habitats of Periyar Tiger Reserve

Habitats	Taxa Richness	Shannon's (H')	Simpson's (D)
Evergreen	5	1.43	0.25
Semigreen	23	2.63	0.11
Deciduous	14	2.32	0.12
Grassland	8	1.92	0.15
Riparian	10	2.07	0.14

throw light into the relatively high diversity of ant fauna as compared to studies done in the Wayanad region of Western Ghats 29 species (Sabu *et al.*, 2008) and 37 species (Anu and Sabu, 2007) were recorded. Absence of dominant Dolichoderines was noted during the study period.

Although specific habitat preference was shown by different species, semi evergreen supported assemblages intermediate to all habitats. True litter ants (Ponerine ants) and tropical climate specialists *Oecophylla* and *Polyrachis* were noted in the litter rich semi evergreen and deciduous forests. *Oecophylla* (Weaver ants) was totally absent from grass land and riparian regions implying on the necessity of broad leaves for their nest construction. This is similar to the findings reported by Narendra *et al.* (2010) in the Sharavathi river basin forests of Western Ghats. Coexistence of Myrmicinae with subordinate Camponotini was noted; a finding characteristic to undisturbed habitats where the dominant Dolichoderines are absent. Elsewhere in the world, similar organisation of the functional groups have been reported (King *et al.*, 1998)

(Reichel and Andersen, 1996). In the disturbed habitats where Dolichoderines are absent, coexistence of Myrmicinae with opportunists has been noted (Pfeiffer *et al.*, 2003; Morrison, 1996). Subordinate Camponotini showed their dominance in the absence of Myrmicinae in the Grassland whereas both coexisted in the Riparian habitat. Similar findings have been reported by Narendra *et al.*, 2010 in the studies conducted in the Karnataka regions of Western Ghats. In this context, studies with intensive ant sampling should be carried out in the Periyar Tiger Reserve to check the global applicability of the functional group model.

This study emphasises the dominancy exhibited by the subfamily *Formicinae* within the ant communities, due to their ability to adapt to different niches with a variety of feeding habits. Less specificity and easy availability of the required resources has resulted in dominance of the subfamily Myrmicinae next to Formicines. Myrmicinae is known to have a diverse range of feeding habits with some being specialist predators, scavengers, seed harvesters and nectarivores (Majer *et*

*al.*, 2001).

Studies done by Anu and Sabu (2007) in the evergreen forests of Wayanad in Western Ghats could also report the dominance of Subfamily Formicinae. In contrast, Myrmecinae forms the bulk of Indian ant diversity (45%) in the studies conducted in the other parts of the country and the subfamily Formicinae occupying the second position (25% of species) with *Camponotus* and *Polyrachis* constituting the majority of the diversity (Bharti, 2012). However, an entirely different pattern with the dominance of Myrmecinae followed by Ponerinae in low and mid elevations and dominance of Formicinae followed by Mymecinae and the absence of Ponerinae in higher elevation was recorded in the studies in elevational pattern of litter ant diversity conducted in the Wayanad forests (Sabu *et al.*, 2008). High richness and abundance of Formicinae and Myrmicinae, in most terrestrial habitats was reported by Varghese (2009) and Ramesh *et al.* (2010). This highlights the importance of further survey to establish dominance of Formicinae in the Periyar Tiger Reserve and other unsurveyed forest of Western Ghats.

Ponerinae subfamily is more specific about its niche requirements and food habits. Harpegnathos saltator a species endemic to the Western Ghats, collected only from the evergreen and semievergreen habitats could survive only in undisturbed systems and is highly specific about its food requirements. Field observations done by Ramachandran *et al.* (2012) in Sharavathi river basin Central Western Ghats have revealed that 90% of the food, brought to the nest by these solitary foragers were flying insects as wasps, bees, and hoppers, other than which, they fed on termites, roaches and other ants. The specific niche and food requirement among *Ponerines*, along with their incompatibility with other *Ponerines* to be in same niches, arguably has resulted in less abundance and low species richness in the subfamily Ponerinae.

Though Subfamily Dolichoderinae was considered to be highly dominant all over the world, not even a single representative of this subfamily was collected in the Periyar Tiger Reserve during the study period. Members of this subfamily especially the most occurring *Tapinoma* sp. acts as an excellent indicator species to determine human interference (Viswanathan and Narendra, 2000).

## Conclusion

This study on ant diversity of different vegetation types of Periyar Tiger Reserve emphasises the dominancy exhibited by the subfamily Formicinae within the ant communities, due to their ability to adapt to

different niches with a variety of feeding habits. Dominancy exhibited by Myrmicinae and Ponerinae subfamilies in only certain habitats has been related to their very specific niche and food requirements. Habitats providing these specific niches were less frequently

present. Behavioural data being sparse for ants represented by very few individuals, limits discussions. Further work is required in cataloguing the needs and requirements of different ant species to understand the species composition in detail.

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### दक्षिण-पूर्वी घाटों में पेरियार बाघ रिजर्व में चींटी वैविध्य का अध्ययन

सरन्या सिवादसन, अनु अन्तो, जायजी के. तथा शाहजू थामस

#### सारांश

सभी पोषण स्तरों पर वातावरण में परिवर्तन को समझते हुये मार्ग-दर्शन करने की क्षमता के कारण चींटी (पिपीलिका) एक विशेष नाभीय वर्ग है। दक्षिण-पश्चिमी घाटों के पेरियार बाघ रिजर्व में चींटियों पर किये गये प्रारंभिक अध्ययन का उद्देश्य वासस्थलों की विभिन्न वनस्पति, किस्मों में इस प्रजाति के संघटन को निर्धारित करना है। रिजर्व की विभिन्न वनस्पति किस्मों से 4 कुलों और 14 वंशों की 31 चींटी प्रजातियों को एकत्र किया गया। इस अध्ययन में, चींटी समुदाय के भीतर उपकुल फॉर्मोसीनाई द्वारा प्रदर्शित प्रमुखता पर जोर दिया गया है, जो विभिन्न परिस्थितियों में इस प्रजाति की अनुकूलन क्षमता के कारण है। हर्पेगंथोस साल्टेटर, पश्चिमी घाटों की देशज प्रजाति तथा पैराट्रिकिना लांगीकार्निस जो आई.यू.सी.एन. की लाल सूची में दर्ज है, को यहां के वासस्थलों से एकत्र किया गया। अध्ययन क्षेत्र के पांच विभिन्न वासस्थलों से एकत्रित 31 प्रजातियों में से चींटी की 24 प्रजातियां समसदाहरित वासस्थलों में पाई गईं, जिसके कारण इस क्षेत्र को प्रजाति बाहुल्य वाले वासस्थलों वाला क्षेत्र माना गया है। वर्तमान अध्ययन में पेरियार बाघ रिजर्व में चींटियों के वैविध्य की झलक मिलती है लेकिन साथ ही दीर्घकालिक अध्ययन की संभावनाओं को रेखांकित किया गया है जिसमें वर्तमान वासस्थलों में चींटी समुदाय को अधिक विस्तार से जानने के लिए सटीक नमूनों और गहन अध्ययन पर जोर दिया गया है।

#### References

- Agosti, D., Majer, J.D., Alonso, L.E. and Schultz, T.R. (2000). *Ants: Standard methods for measuring and monitoring biodiversity*. Smithsonian Institution Press.
- Andersen, A.N. (1997) Using ants as bioindicators: multi-scale issues in ant community ecology. *Conservation Ecology*, 1(1), 8 [online] URL: <http://www.consecol.org/vol1/iss1/art8>.
- Anu, A. and Sabu, T.K. (2007). Biodiversity analysis of forest litter ant assemblages in the Wayanad region of Western Ghats using taxonomic and conventional diversity measures, *Journal of Insect Science* 7.06, available online: [insectscience.org/7.06](http://insectscience.org/7.06). 2007.
- Bestelmeyer, B.T., Agosti, D., Alonso, L.E., Brandao, C.R.F., Brown, W.L., Delabie, J.H.C. and Silvestre, R. (2000). Field techniques for the study of ground-dwelling ants. In: *Ants: Standard Methods for Measuring and Monitoring Biodiversity* (Agosti D., Majer J.D., Alonso L.E. and Schultz T.R., Eds), Smithsonian Institution Press, Washington, London. pp 122–144
- Bharti, H. (2012). Indian ants. Downloaded from [www.antweb.org/india.jsp](http://www.antweb.org/india.jsp) on 14 December 2012.
- Bingham, C.T. (1903). *The fauna of British India, including Ceylon and Burma. Hymenoptera 2. Ants and Cuckoo-Wasps*. London. 506 pp.
- Bolton, B. (1994). *Identification guide to the ant genera of the world*. Harvard University Press. (Cambridge, Massachusetts/London, England). 222pp.
- Bossuyt, F., Meegaskumbura, M., Beenaerts, N., Gower, J.D., Pethiyagoda, K., Roelants, A., Mannaert, M., Wilkinson, M., Bahir, M., Arachchi, M.K., Peter, L.N., Schneider, J.C., Oommen, V.O., Milinkovitch, C.M. (2004). Local endemism within the Western Ghats, Srilanka biodiversity hotspot, *Science*, 306: 479-481.
- Bruehl, C.A., Mohamed, M., Linsenmair, K.E. (1999). Altitudinal distribution of leaf litter ants along a transect in primary forests on Mount Kinabalu, Sabah, Malaysia, *Journal of Tropical Ecology*, 15: 265-277.
- Elmes, G.W. and Wardlaw, J.C. (1982). A population study of the ants *Myrmica sabuleti* and *Myrmica scabrinodis*, living at two sites in the south of England. I. A comparison of colony populations, *Journal of Animal Ecology*, 51: 651–664.
- Fisher, B.L. and Robertson, H. (2002). Comparison and origin of forest and grassland ant assemblages in the high plateau of Madagascar, *Biotropica*, 34: 155-167.
- Fittkau, E.J. and Klinge, H. (1973). On biomass and trophic structure of the central Amazonian rain forest ecosystem, *Biotropica*, 5:2-14.
- Fu, C., Hua, X., Li, J., Chang, Z., Pu, Z. and Chen, J. (2004). Patterns of diversity, altitudinal range and body size among freshwater fishes in the Yangtze River basin, China, *Global Ecology and Biogeography*, 13: 543-552.
- Fu, C., Hua, X., Li, J., Chang, Z., Pu, Z. and Chen, J. (2006). Elevational patterns of frog species richness and endemic richness in the Hengduan Mountains, China: geometric constraints, area and climate effects, *Ecography*, 29: 919-927.

- Grytnes, J.A. and Vetaas, O.R. (2002). Distribution of vascular plant species richness and endemic richness along the Himalayan elevation gradient in Nepal, *Global Ecology and Biogeography*, 11: 291-301
- Holldobler, B. and Wilson E.O. (1990). The ants. Springer- Verlag, Berlin, 732 p,
- Joseph, J., Bhardwaj, A.K and Zacharias, V.J. (1998). A collection of spiders from Periyar Tiger Reserve, Kerala, *Indian Forester*, 124: 869-871
- Kerala Forest Department (2003). Periyar Tiger Reserve- A General Introduction. Report of the India Ecodevelopment Project submitted to World Bank Mission April/May 2003.
- King, J.R., Andersen, A.N. and Cutter, A.D. (1998) Ants as bioindicators of habitat disturbance: validation of the functional group model for Australia's humid tropics, *Biodiversity and Conservation*, 7: 1627-1638.
- Morrison L.W. (1996). The ants (Hymenoptera : Formicidae) of Polynesia revisited: species diversity and the importance of sampling intensity, *Ecography*, 19:73-84.
- Myers, N., Mittermeier, R.A., Mittermeier, C.G., da Fonseca, G.A.B., Kent, J. (2000). Biodiversity hotspots for conservation priorities, *Nature*, 403: 853-858.
- Myers, N. (2003). Biodiversity hotspots revisited, *Bioscience*, 53: 916-917.
- Narendra, A., Reid, S.F. and Hemmi, J.M. (2010). The twilight zone: ambient light levels trigger activity in primitive ants, *Proceedings of Royal Society Bulletin*, 277: 1531-1538.
- Oliver, I. and Beattie, A.J. (1996). Designing a cost effective invertebrate survey: a test of methods for rapid assessment of biodiversity, *Ecological Applications*, 6: 594-607.
- Palot, J., Zacharias, V.J. and Mathew G. (1997). Studies on the Butterflies of Periyar Tiger Reserve, Kerala, India. *Advances in Forestry Research in India*. Vol. XVII. (Ed. Ram Prakash). International Book Distributors, Dehradun, India.
- 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: 1921-1935.
- Radhakrishnan, K.V and Kurup B.M. (2010). Ichthyodiversity of Periyar Tiger Reserve, Kerala, India, *Journal of Threatened Taxa*, 2(10): 1192-1198.
- Ramachandra, T.V, Subash Chandran, M.D, Joshi, N.V., Narendra, A. and Ali T.M. (2012). Ant Species Composition and Diversity in the Sharavathi River Basin, Central Western Ghats, Sahyadri Conservation Series 3. ENVIS Technical Report: 20
- Ramesh, T, Hussain, J.K, Satpathy, K.K, Selvanayagam, M, Prasad, M.V.R. (2010). Diversity, distribution and species composition of ants fauna at department of atomic energy (DAE) campus Kalpakkam, South India, *World Journal of Zoology*, 5(1): 56-65.
- Reichel, H. and Andersen, A.N. (1996). The rainforest ant fauna of Australia's Northern Territory, *Australian Journal of Zoology*, 44: 81-95.
- Sabu, T.K., Vineesh, P.J. and Vinod, K.V. (2008). Diversity of forest litter-inhabiting ants along elevations in the Wayanad region of the Western Ghats, *Journal of Insect Science*, 8: 69.
- Varghese, T. 2009. A review of extant subfamilies, tribes and ant genera in India, *Biosystematica*, 3(2):81-89.
- Viswanathan, G. and Narendra, A. (2000). Impact of urbanization on the diversity of ants in Bangalore, *Journal of Ecobiology*, 12: 115-122.
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