Journal of Agriculture and Ecology Research International
8(1): 1-9, 2016; Article no.JAERI.24590
ISSN: 2394-1073

SCIENCEDOMAIN *international*
www.sciencedomain.org

Preliminary Survey and Ecological Studies on Ant Fauna Diversity in Asir Region, Kingdom of Saudi Arabia

Ala'a H. Asiri[1*], Hamed A. Al- Gharmh[1] and Reda F. Bakr[2]

[1]Department of Biology, Faculty of Science, King Khalid University, Abha, Saudi Arabia.
[2]Department of Entomology, Faculty of Science, Ain Shames University, Egypt.

Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JAERI/2016/24590
Editor(s):
(1) Monica Rosa Loizzo, Department of Pharmacy, Health Sciences and Nutrition of University of Calabria, Italy.
(2) Daniele De Wrachien, Department of Agricultural and Environmental Sciences of the State University of Milan, Italy.
(3) Vincenzo Tufarelli, Department of DETO - Section of Veterinary Science and Animal Production, University of Bari "Aldo Moro", Italy.
Reviewers:
(1) Augusto Loni, University of Pisa, Italy.
(2) Manoel Fernando Demétrio, Universidade Federal da Grande Dourados, Brazil.
(3) Anonymous, Universit´e de Toulouse, France.
Complete Peer review History: http://sciencedomain.org/review-history/14387

Original Research Article

Received 26th January 2016
Accepted 15th April 2016
Published 28th April 2016

ABSTRACT

We report on twelve new records of ants species for the fauna in Asir region: *Camponotus aegyptiacus*, *Camponotus sericeus*, *Camponotus xerxes*, *Cataglyphis bicolor*, *Cataglyphis fortis*, *Cataglyphis niger*, *Lepisiota opaciventris*, *Paratrechina longicornis*, *Crematogaster aegyptiaca*, *Crematogaster senegalensis*, *Monomorium carbonarium*, and *Monomorium salomonis*. Genera like *Cataglyphis*, *Camponotus*, *Crematogaster* and *Messor* gradually dominate the ant fauna and are represented by a maximum number of endemic species with Myrmicinae accounting for the most numerous species followed by Formicinae. The maximum relative abundance and distribution of ant species in Asir province was observed in the Formicinae (*Cataglyphis bicolor*) and in the Myrmicinae (*Messor ebeninus*).

Keywords: Ants; formicidae; survey; diversity; Asir region; Kingdom of Saudi Arabia.

**Corresponding author: E-mail: alaa.h.abdulmotali@outlook.com;*

1. INTRODUCTION

Ants belong to the family Formicidae of the order Hymenoptera with approximately 15,981 valid species and subspecies described worldwide (AntWeb, 2016), of an expected total of 22,000 species [1]. They play an important role in maintaining the natural balance of ecosystem and can be used as bioindicators of environmental changes [2-4]. Ants have been used extensively as bioindicators for used in land monitoring and assessment [5-8], also to disturbances such as fire, grazing and logging [9-11], and to mine site restoration [12,13]. They have also been used as indicator taxa, where the diversity of ants is positively related to biodiversity in arid environments and to monitor the effect of disturbances on biodiversity [14,15].

Ants are considered to be perfect candidate for use as an indicator group for many of reasons: they are highly sensitive to disturbance and environmental conditions and and they respond to any environmental change, they show strong interactions with all trophic levels [16], and they are abundant and found in areas of disturbance. Furthermore, sampling is relatively easy, without requiring enormous expertise and experience. Ants exhibit a high resistance to pollutants, especially to radioactivity [17,18] and to industrial pollutants [19]. The majority of ground dwelling ants live in perennial, colonies with workers having limited foraging ranges [20], allowing for reliable sampling and monitoring that is well-linked to characteristics of the local habitat [21].

Ants are highly diverse and abundant, exhibit many types of relationships with other soil biota, and are found in most terrestrial environments of the planet [22]. Ants play important roles to maintain or restore soil quality [23], the direct and indirect contribution of ants to soil health integrity significantly affecting soil formation by aerating and stirring the soil, direct interactions with plants and animals at all trophic levels, nutrient cycling [24], seed predation [25], seed dispersal and decomposition of organic matter.

Ants may have positive or negative influences in cases where habitats are rehabilitated by seeding plants depending on their seed preferences or on the presence of elaiosomes (food ant rewards) in the seeds because the ants may act as granivores (negative effect) or dispersers (positive effect). Ants are an excellent taxon for biodiversity studies because they are conspicuous and important faunistic elements in most ecosystems. For example, ants contribute as much to soil turnover as terrestrial annelids. In areas with no termites, such as northern temperate regions, ants are also major contributors to the breakdown of wood [26].

2. MATERIALS AND METHODS

2.1 Study Area (Asir Region)

South western region (Fig. 1) is located between latitude 17°30'-21°00' N and longitude 41°30'-44°-30°E. It is entirely different from the rest of the kingdom. The mountain range of Al-Sarawat with its highest peak (Al-Sawdah mountain, 3000-3100 m), near Abha (2094 m) the capital of Asir province, divides the area into two distinct ecological regions. There are the high plateau with the slopes gently eastward from the escarpment to form the highlands of Asir, and to the west the highly jagged-edged mountains terrain to Tehamah Asir that merges westward into the narrow, sandy Red Sea coastal plain, making it the hottest part of the region. The Asir highland receives a variable seasonal rainfall which is higher than in the rest of the kingdom, i.e. 300-500 mm/year as compared with 50-100 mm/year elsewhere.

2.2 Field Techniques

Two field techniques were used to collect and study ants mainly Pitfall trapping(Four traps for each location according to the four geographical directions and a distance between the pitfall traps of about 500 m) and direct sampling (Hand picking). Ants were collected in the field and then put into vials filled with 70% ethanol and tight-fitting caps to retard the evaporation of alcohol. For every sample, the vial was clearly labeled with a code number referring to the location, the date, the habitat....etc. These samples were collected every two weeks for one year (Nov.2013- Oct. 2014).

2.3 Sorting ant Specimens

Two important divided into from the field, ants preparations was the sorting of the materials collected (mixed with soil and other organisms). After field work, ants specimens were important to remove from this other materials as soon as possible in order to prevent damage specimens [27]. Salt-water extraction technique described by [28] was used in order to separate ant specimens from the other materials because of its simplicity and low cost.

Fig. 1. Asir map showing the surveyed localities

2.4 Identification of the Ants to Species

Examination and identification of ants to species rank was carried out by the use of a stereoscopic binocular microscope. Identification of ants to the species rank was obtained by the use of different taxonomic keys [29-33].

2.5 Diversity Data Analysis

Data were analyzed by Incidence-based coverage estimator (ICE). Species richness and Alpha diversity were estimated by using Shannon-Wiener, and Simpson's D diversity indices. The program EstimateS [34] was used to calculate these standard estimators.

3. RESULTS AND DISCUSSION

3.1 Results of Ant Diversity Studies

Study of ant diversity in several places in Asir region, where it was to find new species of ants have been recorded for the first time.

3.2 Diversity of Ants along Elevational Gradient

A total of 1,020 ants belonging to 19 species of 9 genera were collected. *Lepisiota*, *Paratrechina*, *Messor* and *Pheidole* genera were represented by a single species each, while *Camponotus*, *Cataglyphis*, *Monomorium*, *Crematogaster* and *Tetramorium* were represented by 4, 4, 3, 2 and 2 species respectively (Table 2 & Fig. 2). Formicinae were represented by 4 genera and Myrmicinae by 5 genera. Relative abundance was higher for *Messor ebeninus*, *Cataglyphis bicolor* and *Crematogaster senegalensis* (17.65%; 13.93% and 11.67% respectively) while *Lepisiota opaciventris* had the lowest 0.49%. Hand picking yielded higher number of specimens (68.23%) than Pitfail Trapping (31.77%) (Fig. 2).

At <2000 m the average temperature was 25℃, relative humidity 51%, wind speed was 7 km/h and precipitation 35 mm. The total catch in terms the number of specimens was 393. At the site of KM, the number of specimens collected was 132 (33.59%) with a maximum of 6 different species recorded. The genus *Crematogaster* was the most abundant with *Crematogaster senegalensis* 119 representing 30.28% of the total catch at this elevation and most the specimens were collected by hand picking method. Formicinae were represented mainly by the genus *Camponotus, Camponotus sericeus* has maximum catch of 78 specimens and forming the largest percentage 19.85%, again hand picking method was found to be the most effective followed by pitfall (Table 2 & Fig. 2).

At >2000 m the average temperature was 15.5℃, relative humidity 45%, wind speed was 10 km/h and precipitation 30 mm. The total catch in terms the number of specimens was 627. In terms of abundance, 176 (28.07%) specimens with 7 different species were recorded at the site of AB, while the higher diversity, with 9 different species, was observed at the site of BA. The genus *Messor* was the most abundant genus with *Messor ebeninus* representing 22.17% of the total catch and most of the specimens were collected by the hand picking method. Formicinae represented 51.35% of the specimens, with the genus *Cataglyphis* forming the bulk (32.69%), *Cataglyphis bicolor* accounting for the higher catch with 103 specimens (Table 2 & Fig. 2).

Table 1. Data of the surveyed sites in Asir province with number of specimens at each site

Area (Area more than 2000 m elevation)		Coordinates of latitude and longitude		Above sea level (altitude) asl	Total no. specimen collected	No. species
		N	E			
1	Abha (AB)**	18°14'460"	42°31'767"	2094 m	176	7
2	Al-Sawdah (AS)**	18°27'173"	42°38'400"	3000 - 3100 m	50	2
3	Sarat Abidah (SA)**	18°00'852"	43°09'00"	2380 m	56	2
4	Ahad Rafidah (AR)**	18°21'216"	42°84'378"	2090 m	28	2
5	Dhahran Al-Janoub (DJ)**	17°39'56.1"	43°31'00.1"	2100-2570 m	40	4
6	Ballahmar (BA)**	18°54'947"	42°40'899"	2250 m	150	9
7	Ballasmar (BS)**	18°79'296"	42°25'570"	2250 m	20	2
8	Tanomah (TA)**	18°89'215"	42°22'767"	2148 m	34	3
9	Al-Namas (AN)**	19°07'12"	42°07'48"	2600 m	73	4
(Area below 2000 m elevation)						
10	Muhayil (MU)*	18°34'760"	42°02'151"	456 m	115	5
11	Al-Majardah (AM)*	19°12'844"	41°92'460"	2000 m	33	4
12	Khamis Mushayt (KM)*	18°29'153"	42°73'874"	1850 - 2000 m	132	6
13	Rijal Almaa (RA)*	18°14'608"	42°16'500"	1000- 1500 m	113	5

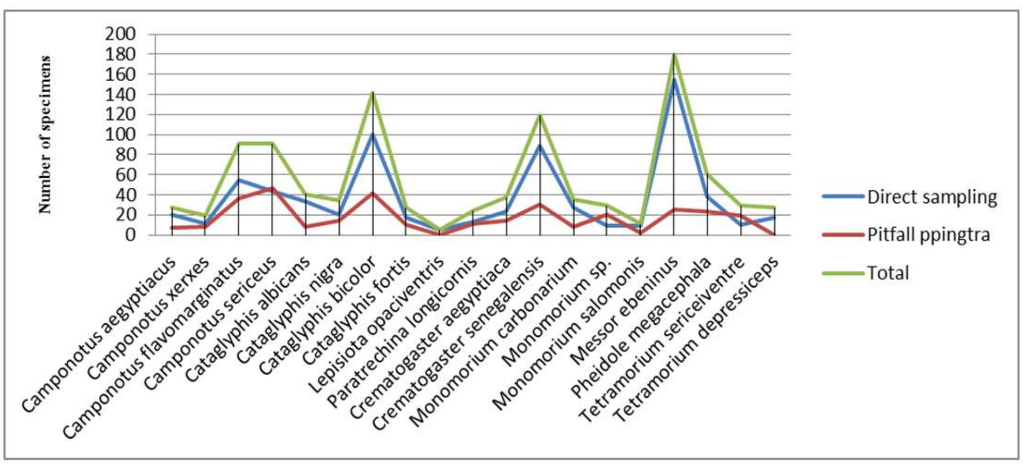

Fig. 2. Abundance effectiveness of both collection methods in both elevation

Table 2. Mean environmental parameters in both elevation gradients in 2013-2014

Altitude	Less than 2000 m	More than 2000 m
Temperature (Mean)	25	15.5
Relative humidity	51	45
Wind speed	7	10
Precipitation	35	30
Specimen	393	627

Table 3. Distribution of the ants in the Asir region, KSA

	Region species	Al- Sawdah	Al-Namas	Dhahran Al Janoub	Sarat Abidah	Ballahmar	Ballasmar	Tanomah	Abha	Ahad Rafidah	Al- Majardah	Khamis Mushayt	Rijal Almaa	Muhayil
subfamily: Formicinae	*Camponotus aegyptiacus* Emery												++	
	Camponotus xerxes Forel								+					
	Camponotus flavomarginatus Mayr			+	++	+		+	++			+		
	Camponotus sericeus (Fabricius)									+	+	+++	+	+
	Cataglyphis albicans (Roger*)*		++											
	Cataglyphis nigra (André)		+					++						
	Cataglyphis bicolor (Fabricius)			+	++				+++		+	+		+
	Cataglyphis fortis (Forel)	+							+					
	Lepisiota opaciventris (Finzi)		+											
	Paratrechina longicornis (Latreille)												+	+
subfamily: Myrmicinae	*Crematogaster aegyptiaca* Mayr					+	+		+					
	Crematogaster senegalensis Roger										+		++	+++
	Monomorium carbonarium (Smith)					+			+	+				
	Monomorium sp.					+					+	+		+
	Monomorium salomonis (Linnaeus)					+								
	Messor ebeninus Santschi	++		+		+++	+	+	++			++		
	Pheidole megacephala (Fabricius)			+		+						+	++	
	Tetramorium sericeiventre Emery		+			+								
	Tetramorium depressiceps Menozzi					+								

(+) low density, (++) moderate density and (+++) high density

Table 4. Showing alpha diversity of ants in both elevational gradients

Sample	Alpha SD (Analytical)	Shannon mean	Simpson mean
Direct sampling	0.79	2.47	9.30
Pitfall trapping	0.43	2.56	12.14

4. DISCUSSION

4.1 Ants Diversity along Elevational Gradient

Several studies have examined the effects of elevational gradients on ant diversity. In general these studies have revealed two patterns: one showing a steady decline in ant diversity from low to high elevations [35,36], and another a pattern of mid-elevation peak in species richness [37-39]. One common element to these studies is that they have tended to quantify biodiversity using species diversity metrics that are based on morphospecies designations or morphologically determined taxonomic units [40].

In the present work, we also used morphology as a direct measure of the levels of ant functional diversity present at different elevational gradients. Therefore, we categorized our study area in two section one is <2000 m and the other >2000 m with 13 collecting sites. Also we tried to explain ant species to a set of guilds using both ecological information as well as a group of functionally significant morphological traits. In general, we found that functional diversity peaked at mid-elevation (although non-significantly). The results of these guild proportionality analysis show that at low and high elevations, ant communities contain uneven numbers of species from each guild and contain less of the overall variation in ant functional morphology suggesting that environmental factors like temperature; humidity etc. may previously controlled these communities. As have mentioned we found a mid-elevational peak of species density that differs in both size and shape depending on the season and year. Abha (AB) and Ballahmar (BA) sites were dominant in terms of number of species (Table 1). These results are in accordance with studies that found mid-elevational peaks of ant species density [41-43]. This peak was that found to change in scale and position depending on the season (Table 2 & Fig. 2). Larger community structure, abundance and variation were found in these sites, which may be because of suitable ecological factors like temperature, and humidity and these areas are known to have maximum rainfalls in kingdom (Table 2). Fewer species were observed in the dry season than in the wet season (Table 2). In our dataset, the seasonal change in the elevation–species density relationship is due to greater seasonal fluctuation at low elevations. These patterns of species density appear to be entirely explained by the effects of mean temperature and available area. In general, a weak linear decline in abundance across elevation was seen in the wet season (Table 2 & Fig. 2).

Species richness by different indices have been depicted in (Fig. 2) and species abundance and effectiveness of sampling methods by Sobs (species observed) while Alpha diversity indices have been depicted in (Table 4). The data generated reflected that with decreasing in temperature and humidity, composition of species changes; as in case of Myrmicinae the generalist species are replaced by more high altitude specialists like *Messor ebeninus* Santschi, *Crematogaster senegalensis* Roger, and *Cataglyphis bicolor bicolor* (Formicinae). In the case of the Formicinae the interpretation resembles Myrmicinae as cold specialist *Camponotus sericeus* increases in abundance. But interestingly, the overall abundance increases from 1800 m to 2500 m with the number of species staying almost the same at both the elevations. For the time being, it is difficult to conclude that with more increase in altitude, the number of species and abundance would increase, but it is what we observed that with an increase in altitude in Asir.

4.2 Ants Taxonomy with Distribution

The results of the present study record the presence of nineteen species: *Camponotus aegyptiacus*, *Camponotus sericeus*, *Camponotus xerxes*, *Camponotus flavomarginatus*, *Cataglyphis albicans*, *Cataglyphis bicolor*, *Cataglyphis fortis, Cataglyphis nigra, Lepisiota opaciventris*, *Paratrechina longicornis*, *Crematogaster aegyptiaca*, *Crematogaster senegalensis*, *Messor ebeninus*, *Monomorium carbonarium*, *Monomorium* sp., *Monomorium salomonis*, *Pheidole megacephala*, *Tetramorium sericeiventre* and *Tetramorium depressiceps*) from two subfamilies (Formicinae and Myrmecinae).

Twelve species were new record in Asir region: *Camponotus aegyptiacus*, *Camponotus sericeus*, *Camponotus xerxes*, *Cataglyphis bicolor*, *Cataglyphis fortis, Cataglyphis nigra, Lepisiota opaciventris*, *Paratrechina longicornis*, *Crematogaster aegyptiaca*, *Crematogaster senegalensis*, *Monomorium carbonarium* and *Monomorium salomonis*.

Five species were previously recorded and also found in new places: *Camponotus flavomarginatus, Messor ebeninus*, *Pheidole megacephala, Tetramorium sericeiventre* and *Tetramorium depressiceps* and two species were previously recorded in Asir region: *Cataglyphis albicans* and *Monomorium* sp.

5. CONCLUSION

Diversity of Asir region ant fauna in relation with the elevation gradient reveals that the functional diversity peaked at mid-elevation in Asir region. The data generated reflected that the composition of species changes in accordance with environmental factors like temperature, humidity etc. More ant individuals and species were found in the wetter parts of the elevation gradient rather than in hot and dry areas. These results suggest a strong environmental, control on ant diversity patterns in Asir region of KSA. At higher elevations, genera like *Cataglyphis, Camponotus, Crematogaster* and *Messor* gradually dominate the ant fauna and are represented by a higher number of endemic species. Maximum relative abundance and distribution of ant species in Asir province were observed for the Formicinae *Cataglyphis bicolor* and the Myrmicinae *Messor ebeninus*.

ACKNOWLEDGEMENTS

The authors are indebted to the King Abdulaziz City for Science and Technology (KACST) Saudi Arabia, for financial support of this work (KACST: AI-34-0225).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Agosti D, Johnson NF. La nueva taxonomía de hormigas. In: Introducción a las hormigas de la región Neotropical (Ferandez F ed): Instituto de Investigación de Recursos Biológicos Alexander von Humboldt, Bogotá. 2003;45-48.
2. Maryati M. Ants: An indicator for the tropical rain forest. Manual for international plot course on environmental evaluation using insects as indicator of biodiversity: Ant ecology, taxonomy collecting methods and identification 17 March - 7 April 1997. Kota Kinabalu. Tropical Biology and Conservation Unit, Universiti Malaysia Sabah and International Institute of Entomology; 1997.
3. Peck SL, Mcquaid B, Campbell CL. Using ant species (Hymenoptera: Formicidae) as a biological indicator of agroecosystem condition. Environmental Entomology. 1998;27:1102-1110.
4. Toda M, Kitching RL. IBOY-DIWPA: Biodiversity assessment program in the western pacific and Asian region. International Net Work for Biodiversity Research Diversity (IBOY). Western Pacific and Asia; 1999.
5. Majer JD. Ants: Bioindicators of minesite rehabilitation, land-use and land conservation. Environmental Management. 1983;7:375-383.
6. Greenslade PJM, Greenslade P. Invertebrates and environmental assessment. Environment and Planning. 1984;3:13-15.
7. Andersen AN. The use of ant communities to evaluate change in Australian terrestrial ecosystems: A review and a recipe. Proceedings of the Ecological Society of Australia. 1990;16:347-357.
8. Andersen AN. Measuring invertebrate biodiversity surrogates of ant species richness in the Australian seasonal tropics. Mem. Mus. Victt. 1997;56:355-359.
9. Neumann FG. Responses of foraging ant populations to high-intensity wildfire, salvage logging and natural regeneration processes in Eucalyptus regnans regrowth forest of the Victorian central highlands. Australian Forestry. 1992;55:29-38.
10. York A. The long term effects of fire on forest ant communities: Management implications for the conservation of biodiversity. Mem. Queensl. Mus. 1994;36:227-239.
11. Vanderwoude C, Andersen AN, House APN. Ant communties as bio-indicators in relation to fire management of spotted gum (Eucalyptus maculata Hook.) forests in south-east Queensland. Memoirs of the Museum of Victoria. 1997;56:671-675.
12. Majer JD. The influence of ants on seeding operations in Northern Australian mined areas. Reclam. and Reveg. Resear. 1984; 2:299-313.
13. Majer JD. Recolonisation by ants of rehabilitated mineral sand mines on North Stradbroke island, Queensland, with particular reference to seed removal. Aust. J. Ecol. 1985;10:31-48.
14. Andersen AN, Morrison S, Belbin L, Ashwath N, Brennan K. The role of ants in minesite restoration in the Kakadu region of Australia's Northern Territory, with particular reference to their use as bioindicators. Supervising Scientist Report 130, Supervising Scientist, Canberra. 1998;98.

15. Andersen AN, Parr CL, Lowe LM, Müller WJ. Contrasting fire-related resilience of ecologically dominant ants in tropical savannas of Northern Australia. Diversity and Distributions. 2007;13:438-446.
16. Briese DT. The effect of ants on the soil of a semi-arid saltbush habitat. Insectes Sociaux. 1982;29:375-382.
17. Torossian C, Causse R. Effets des radiations gamma sur la fertlite et la longevite des colonies de Dolichoderus quadripunctatus. Compte rendu du Colloque ``Isotopes and radiation in entomology''. International Atomic Energy Agency, Vienna. 1968;155-164.
18. Le Masne G, Bonavita-Cougourdan A. Premiers results tsd'une irradiation pro-longee au cesium sur les populations de fourmis en Haute-Provence. Ekologia Polska. 1972;20:129-144.
19. Petal J, Jakubczyk H, Chmielewski K, Tatur A. Response of ants to environmental pollution. In progress in Soil Zoology (Vabek J, ed.). Prague: Czechoslovakia Academy of Sciences. 1975;363-373.
20. Hölldobler B, Wilson EO. The ants. The Belknap Press of Harvard University Press, Cambridge, Massachusetts, USA. 1990;732.
21. Alonso LE. Ant conservation: Current status and call for action. In L. Lach, CL. Par & KL. Abbott (Eds), Ant Ecology. Oxford University Press. 2010;59-74.
22. Folgarait PJ. Ant biodiversity and its relationship to ecosystem functioning: A review. Biodiversity and Conservation. 1998;7:1221–1244.
23. Lobry de Bruyn L. Ants as bioindicators of soil function in rural environments. Agriculture, Ecosystems & Environment. 1999;74:425-441.
24. Hutson BR. The role of fauna in nutrient turnover. In: JD. Majer (ed.), Animals in primary succession: The role of fauna in reclaimed lands. Cambridge University Press, Cambridge. 1989;51-70.
25. Majer JD. Rehabilitation of disturbed land: Long-term prospects for the recolonization of fauna. Proceedings of the Ecological Society of Australia. 1990;16:509-519.
26. Hansen LD, Klotz JH. The carpenter ants of the United States and Canada. Comstock Publishing Associates, Ithaca, New York. 2005;204.
27. Lattke JE. Specimen processing—building and curating an ant collection. In Agosti DJD, Majer LE. Alonso & TR. Schultz (eds.), Ants: Standard methods for measuring and monitoring biodiversity. Smithsonian Press, Washington. 2000;155–171.
28. Agosti D, Majer JD, Alonso LE, Schultz TR. Ants: Standard methods for measuring and monitoring biodiversity. Smithsonian Institution Press, Washington and London. 2000;280.
29. Collingwood CA. Hymenoptera: Fam. formicidae of Saudi Arabia. Fauna of Saudi Arabia. 1985;7:230-302.
30. Agosti D. Review and reclassification of Cataglyphis (Hymenoptera Formicidae). Journal of Natural History. 1990;24:1457-1505.
31. Bolton B. A new general catalogue of the ants of the World. Harvard Univ. Press, Cambridge, Mass. 1995;504.
32. Collingwood CA, Agosti D. Formicidae (Insecta: Hymenoptera) of Saudi Arabia (Part 2). Fauna of Saudi Arabia. 1996;15: 300-385.
33. Cagniant H. Le genre cataglyphis foerster, 1850 au Maroc (Hyménoptères Formicidae). Orsis. 2009;24:41-71.
34. Colwell RK, Estimate S. Statistical estimation of species richness and shared species from samples. Version 8.2; 2009. Available:http://viceroy.eeb.uconn.edu/EstimateS
35. Brühl CA, Gunsalam G, Linsenmair KE. Stratification of ants (Hymenoptera, Formicidae) in a primary rain forest in Sabah, Borneo. Journal of Tropical Ecology. 1998;14:285-297.
36. Janzen DH, Ataroff M, Fariñas M, Reyes S, Rincon N, Soler A, Soriano P, Vera M. Changes in arthropod community along an elevational transect in the Venezuelan Andes Biotropica. 1976;8:193-203.
37. Fisher BL, Robertson HG. Comparison and origin of forest and grassland ant assemblages in the high Plateau of Madagascar (Hymenoptera: Formicidae). Biotropica. 2002;34:155-167.
38. Sabu TK, Vineesh PJ, Vinod KV. Diversity of forest litter-inhabiting ants along elevations in the Wayanad region of the Western Ghats. Journal of Insects Science. 2008;8:69.
39. Samson DA. Rickart EA, Gonzales PC. Ant diversity and abundance along an elevational gradient in the Philippines. Biotropica. 1997;29:349-363.

40. Gotelli NJ, Colwell RK. Quantifying biodiversity: Procedures and pitfalls in the measurement and comparison of species richness. Ecology Letters. 2001;4:379-391.
41. Fisher BL. Ant diversity patterns along an elevational gradient in the Réserve Naturelle Intégrale d'Andohahela, Madagascar. Fieldiana Zoology (n.s.). 1999;94:129-147.
42. Sanders NJ. Elevational gradients in ant species richness: Area, geometry, and Rapoport's rule. Ecography. 2002;25:25-32.
43. Bharti H, Sharma YP, Bharti M, Pfeiffer M. Ant species richness, endemicity and functional groups, along an elevational gradient in the Himalayas. Asian Myrmecology. 2013;5:79–101.

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/14387