

Preliminary survey and ecological studies on ant fauna diversity in Asir region, Kingdom of Saudi Arabia

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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.

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1. INTRODUCTION

Ants belong to the family Formicidae of the order Hymenoptera. With approximately 16000 valid species and subspecies described worldwide (see AntWeb, 2016), of an expected total of about 22,000 species (Agosti and Johnson, 2003). Ants are much more diverse than the other social insects such as termites, bees and wasps (Wilson, 1990; Bolton, 1995). They play an important role in maintaining the natural

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43 balance of ecosystem and can be used as bioindicators of environmental changes (Maryati, 1997; Peck
 44 *et al.*, 1998; Toda and Kitching, 1999). They also play important ecological roles, having direct
 45 interactions with the soil, plants and animals at all trophic levels. Many of these roles are related to
 46 paedogenesis, nutrient cycling (Hutson, 1989), seed predation (Andersen, 1990; Majer, 1990) and seed
 47 dispersal (Majer, 1990). Ants are considered to be an ideal candidate for use as an indicator group for a
 48 number of reasons: they are abundant and ubiquitous in areas of disturbance (Andersen, 1990), they
 49 exhibit strong interactions with all trophic levels (Briese, 1982), and most ants have stationary nests and
 50 restricted foraging ranges which reduce competition between ant species (Alonso, 2000). They are
 51 highly sensitive to environmental conditions and disturbance and they respond rapidly to environmental
 52 change (Vanderwoude *et al.*, 1997a; Andersen 1990). Furthermore, sampling is relatively easy, without
 53 requiring enormous expertise and experience.

54 Assessments of biodiversity and its conservation have become important issues given the current rates of
 55 habitat destruction (Magurran 2004; Alonso 2010). However, complete surveys of all taxonomic groups
 56 in a given area are impractical or even impossible. Thus, it is useful to focus resources on taxa that are
 57 ecologically important, diverse, abundant, easy to sample/monitor, taxonomically stable, and indicators of
 58 other taxonomic diversity because this allows for a more rapid assessment of diversity (Ellison 2012).

59 Even if diversity of a focal taxon does not always correlate with diversity of other taxa (Oliver *et al.*,
 60 1998), surveys of single taxa provide knowledge of that group and increase our understanding of local
 61 biodiversity (Alonso 2000; Ellison 2012).

62 Understanding the natural history of a focal taxon is important in relation to elaborating biodiversity and
 63 using the information for conservation purposes (Alonso 2010). In particular, determining the effects of
 64 regional and local environments on abundance and distribution of focal taxa is critical (Magurran 2004;
 65 Alonso 2010).

66 Ants (Hymenoptera: Formicidae) are an excellent taxon for biodiversity studies because they are
 67 conspicuous and important faunistic elements in most ecosystems. For example, ants contribute as much
 68 to soil turnover as terrestrial annelids (Hölldobler and Wilson 1990). In areas with no termites, such as
 69 northern temperate regions, ants are also major contributors to the breakdown of wood (Hasen and Klotz
 70 2005). Ants are also excellent focal taxa for study and monitoring since they are found abundantly in most

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Commentaire [2]: See also some other well known references related with ants as bioindicators such as: Andersen (1997); King *et al.* (1998); Lobry de Bruyn (1999).

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Commentaire [3]: See a review on the role of ants as ecosystem engineers in Folgarait (1998).

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78 terrestrial ecosystems (Majer 1983; Hölldobler and Wilson 1990). The majority of ground dwelling ants
79 live in perennial, sessile colonies with workers having limited foraging ranges (Hölldobler and Wilson
80 1990), allowing for reliable sampling and monitoring that is well-linked to characteristics of the local
81 habitat (Alonso 2010). Ants have been used as indicator taxa, most notably in Australia, where their
82 diversity of ants is positively related to biodiversity in arid environments. They have also been used to
83 monitor the effect of disturbances, such as mining, on biodiversity (Andersen et al., 1998; Andersen et
84 al., 2007). Economically, ants are also important, having both positive and negative influences.

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86 2. MATERIAL AND METHODS

88 Study area (Asir region)

89 South western region (Fig.1) is located between latitude 17°30'-21°00' N and longitude 41°30'-44°30' E. It
90 is entirely different from the rest of the kingdom. The mountain range of Al-Sarawat, with its highest peak
91 (Al-Sawdah mountain, 3000-3100 m), near Abha (2093.96 m) the capital of Asir province, divides the area
92 into two distinct ecological regions. There are the high plateau with the slopes gently eastward from the
93 escarpment to form the highlands of Asir, and to the west the highly jagged-edged mountains terrain to
94 Tehamah Asir that merges westward into the narrow, sandy Red Sea coastal plain, making it the hottest
95 part of the region. The Asir highland receives a variable seasonal rainfall which is higher than in the rest
96 of the kingdom, i.e. 300-500 mm/year as compared with 50-100 mm/year elsewhere.

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97 Field techniques

98 Two field techniques were used to collect and study ants mainly Pitfall trapping and direct sampling (Hand
99 picking). Ants were collected in the field and then put into vials filled with 70% ethanol and tight-fitting
100 caps to retard the evaporation of alcohol. For every sample, the vial was clearly labeled with a code
101 number referring to the location, the date, the habitat....etc. These samples were collected every two
102 weeks for one year (Nov.2013- Oct. 2014).

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103 Sorting ant specimens

104 The first step in ant specimen preparations was the sorting of the material collected from the field. After
105 field work, ant specimens were usually contained in vials and jars and were mixed with soil, other

128 organisms and miscellaneous matter. It was important to remove the ant from this other materials as soon
129 as possible in order to prevent damage to specimens by abrasive particles and to avoid the formation of
130 coating of clay and mineral salts on specimens. Salt-water extraction technique described by (Agosti et
131 al., 2000) was used in order to separate ant specimens from the other materials because of its simplicity
132 and low cost.

Commentaire [8]: It was unnecessary to copy almost literally this paragraph from the chapter by Latke in Agosti et al. 2000 (pp. 155-156). At least you should have to cite it.

133 Identification of the ants to species

134 Examination and identification of ants to species rank was carried out by the use of a stereoscopic
135 binocular microscope. Identification of ants to the species rank was obtained by the use of different
136 taxonomic keys (Collingwood, 1985; Agosti, 1990; Bolton, 1995; Collingwood & Agosti, 1996;
137 Cagniant, 2009).

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138 Specimens storage

139 Since a sample of ants was mounted, the remaining specimens were kept into alcohol vials. The alcohol
140 used for storage was ethanol at a concentration of 70%. This alcohol collection was checked three times
141 a year and empty vials were provided with additional alcohol. The risk of desiccation of vials was avoided
142 by sorting the vials in a large jar that also filled with ethanol. For dry specimens, they were sorted in
143 drawers that are airtight. Damage was reduced by adding naphthalene to drawers to protect collection
144 against insect attack.

Commentaire [9]: Not really necessary.

145 Diversity data analysis

146 Data were analyzed by Incidence-based coverage estimator (ICE). Species richness and Alpha diversity
147 were estimated by using Shannon Wjener, and Simpson's D diversity indices. The program EstimateS
148 (Colwell, 2009) was used to calculate these standard estimators.

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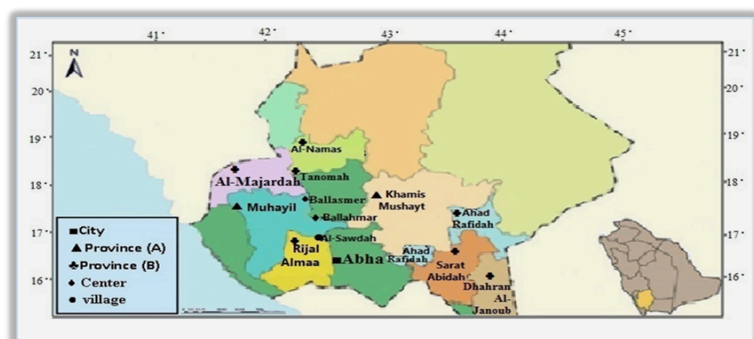


Fig. 1. Asir map showing the surveyed localities.

3. RESULTS AND DISCUSSION

Results of ant diversity studies

Table 1. Data of the surveyed in Asir province along 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"	2093 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"	2000 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

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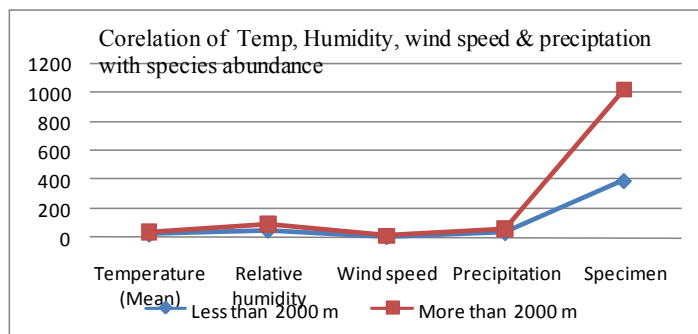
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11	Al-Majardah (AM)*	19°12'844"	41°92'460"	2000 m	33	4
12	Khamis Mushayt (KM)*	18°29'153"	42°73'874"	1850 - 2000 m	132	6
13	Rijal Almaa (RA)*	18°14'608"	42°16'500"	1000- 1500 m	113	5

Commentaire [10]: The altitude is the same as for Ahad Rafidah but these two sites are classed in different elevation groups. Why?

*=Study area below 2000 m elevation; **= Study area more than 2000 m elevation.

Fig. 2. Showing correlation of temperature, humidity, wind speed and precipitation with species abundance in 2013-2014.



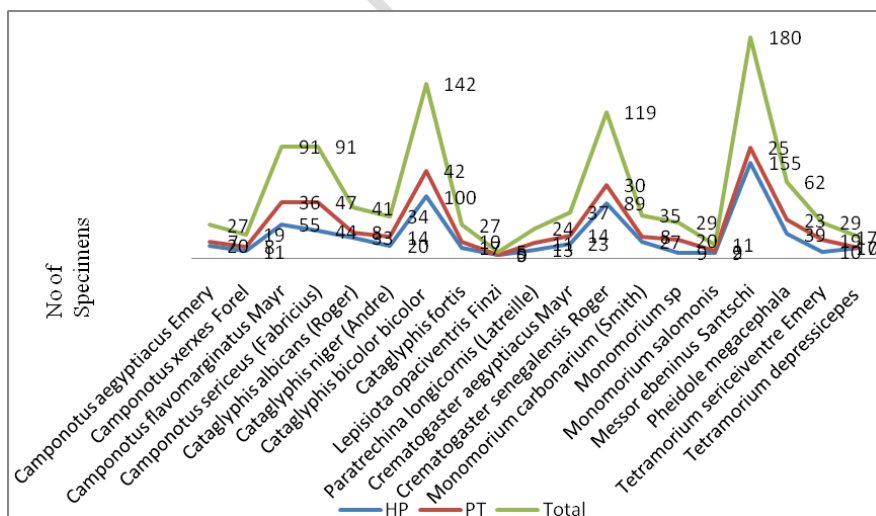
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Commentaire [11]: You cannot represent all these variables (temperature, relative humidity, wind speed, precipitation, specimens) using the same scale. What does represent the y axis and which are the units used? This figure does not show anything and surely not any correlation of any type. It has to be completely modified.

Fig. 3. Abundance effectiveness of both collection methods in both elevation



Commentaire [12]: What is the significance of 'HP' and 'PT' in this figure? I guess that is for 'hand-picking' and 'pitfall trapping', but this has to be indicated in the legend. Moreover you need an y axis on your graph with a scale.

173 Table.2. Distribution of the ants in the Asir region, KSA

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

Commentaire [13]: It would be much more efficient to class the columns (collecting sites) in decreasing order on the base of their altitude to facilitate the lecture of the distribution of the species according to an elevational gradient since, finally, it was the main objective of the presentation of these results.

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At >2000 m (Table 1 & Fig. 2) the average temperature was 15.5°C, relative humidity 45%, wind speed 10 km/h and precipitation 30mm. The total catch in terms of 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 (16.43%). Again hand picking method was found to be most effective followed by pitfall (Table 2 & Fig. 3).

Discussion

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: a steady decline in ant diversity from low to high elevations (Brühl et al., 1998; Janzen et al., 1976), or a pattern of mid-elevation peak in species richness (Fisher & Robertson 2002; Sabu et al., 2008; Samson et al., 1997). 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 (Gotelli & Colwell 2001). 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 sections: one <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 have controlled these communities. As have mentioned earlier that found a mid-elevational peak of species

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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 found mid-elevational peaks of ant species density (e.g. Fisher, 1999; Sanders, 2002; Bharti et al., 2013). This peak was found to change in scale and position depending on the season (Fig. 2 & 3). Larger community structure, abundance and variation was found in these sites, may be because of suitable ecological factors like temperature, and humidity and these areas are known to have maximum rainfalls in kingdom (Fig. 2). Fewer species were observed in the dry season than in the wet season (Fig. 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 (Fig. 2&3).

Species richness by different indices have been depicted in (Fig. 3) and species abundance and effectiveness of sampling methods by Sobs (species observed) while Alpha diversity indices have been depicted in (Table. 3). The data generated reflects that with decrease 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*, *Crematogaster senegalensis*, and *Cataglyphis bicolor*. In the case of the Formicinae the interpretation resembles Myrmicinae as cold specialist *Camponotus sericeus* increases in abundance. But interestingly, overall abundance increases from 1800 m to 2500 m with the number of species staying almost the same at both 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 with an increase in altitude in Asir.

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*

Commentaire [23]: I don't understand.

Commentaire [24]: I don't understand.

Commentaire [25]: Nothing of that is evident in figures 2 & 3. Furthermore, where did you give the information that you were studying seasonal effect? You had to note it in the Methods section and to plan it in your protocol. In any case, no data support your assertion.

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355 salomonis, *Pheidole megacephala*, *Tetramorium sericeiventre* and *Tetramorium depressiceps*,
 356 from two subfamilies (Formicinae and Myrmecinae).
 357 Twelve species were new record in Asir region: *Camponotus aegyptiacus*, *Camponotus*
 358 *sericeus*, *Camponotus xerxes*, *Cataglyphis bicolor*, *Cataglyphis fortis*, *Cataglyphis nigra*,
 359 *Lepisiota opaciventris*, *Paratrechina longicornis*, *Crematogaster aegyptiaca*, *Crematogaster*
 360 *senegalensis*, *Monomorium carbonarium* and *Monomorium salomonis*.
 361 Five species were previously recorded and also found in new places: *Camponotus*
 362 *flavomarginatus*, *Messor ebeninus*, *Pheidole megacephala*, *Tetramorium sericeiventre* and
 363 *Tetramorium depressiceps*, and two species were previously recorded in Asir region:
 364 *Cataglyphis albicans* and *Monomorium* sp.

366 4. CONCLUSION

367
 368 Diversity of Asir region ant fauna in relation with the elevation gradient reveals that the functional diversity
 369 peaked at mid-elevation in Asir region. The data generated reflect that the composition of species
 370 changes in accordance with environmental factors like temperature, humidity etc. More ant individuals
 371 and species were found in the wetter parts of the elevation gradient than in hot and dry areas. These
 372 results suggest a strong environmental control on ant diversity patterns in Asir region of KSA. At higher
 373 elevations, genera like *Cataglyphis*, *Camponotus*, *Crematogaster* and *Messor* gradually dominate the ant
 374 fauna and are represented by a higher number of endemic species. Maximum relative abundance and
 375 distribution of ant species in Asir province were observed for the formicine *Cataglyphis bicolor* and the
 376 myrmicine *Messor ebeninus*.

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