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Assessing fluctuation of ant populations in a distinct ecological habitat to track climate change effects

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Abstract. *Majeed W, Khawaja M, Rana N. 2021. Assessing fluctuation of ant populations in a distinct ecological habitat to track climate change effects. Biodiversitas 22: 2722-2727.* Ants are an indicative group of terrestrial invertebrates that play an important role in soil fertility by clearing the soil surface of vegetation. This study focuses on the composition and structure of ant communities in two sampling stations: Domestic and Wild areas. Ant fauna was collected over a period of six months using an inline-fixing technique combined with pitfall traps and hand sampling. A total of 30 ant species were collected, belonging to 15 genera in four subfamilies: Formicinae, Myrmicinae, Dolichoderinae, and Dorylinae. The maximum population was recorded in the Wild area due to dense forest vegetation present at this station. The most abundantly found species in the Domestic area was *Lasius niger*, while *Formica* spp. was most common in the Wild area. Diversity (H) and Margalef Richness indices were recorded higher for the Wild habitat, while Evenness was found higher in the Domestic habitat. Statistical analysis showed that the abundance and species richness were highly significant for both habitats ($p < 0.001$). Ant populations showed significant variation with temperature and humidity; for example, an increase in temperature and low humidity favored the abundance of ants. Being the first such study in the region, the results add significantly to the understanding of this terrain's ecology.

Keywords: Abundance, ant, cosmopolitan, distribution, social insect

INTRODUCTION

Mountainous, arid, and semi-arid regions represent nearly 80% of Pakistan's total landmass, while abruptly shifting altitude results in highly varied species composition across short distances (Ahmed et al. 2019a, b). While umpteen experts claim that the country has rich biodiverse fauna (Khan and Zaman 2015), actual biodiversity estimation is far from conclusive. Furthermore, the region faces many threats to its biological diversity, such as soil erosion, deforestation, overgrazing, climate change, loss of niche species, waterlogging, salinity, and habitat degradation (Baig and Al-Subaiee 2009; Nabi et al. 2017; Nabi et al. 2019).

Despite multifarious efforts in the world's ecological regions, limited data is available about the ecosystems containing arthropods, including ants. These ubiquitous insects belong to the order Hymenoptera and are pre-eminent in ecological importance. Ants are also considered naturally species-rich fauna when compared to other insect groups. They are a well-known social insect group (Diamé et al. 2018) that carry out various functions such as predator, prey, detritivore, and herbivore. Even though arthropods consist of 78% of all known living fauna species (Zhang 2013) their comprehensive analysis on a global scale is still lacking (Legros et al. 2019). Ants vary significantly with 12,500 species found widely distributed across the earth (Dieng et al. 2016). They are genuinely cosmopolitan and exist across several different ecosystems, including forests, damp places, water sources, and drylands. Given this remarkable presence, it is no wonder that scientists and researchers frequently use ant diversity as a bioindicator to determine ecosystem and environmental changes (Gibb et al. 2015; Carvalho et al. 2020; Oberprieler and Andersen 2020).

The role of ants as a bioindicator in habitats has been demonstrated in several experiments (Andersen 2018). Ant diversity and distribution greatly influence faunal community dynamics, making understanding such patterns a prerequisite for most conservational programs (Abbott et al. 2010). Some ecological changes are also predicated on the availability of food resources. For instance, in the rainy season, plenty of food is available for domestic and wild insects which promotes the detritivores and decomposer species of insects during this time (Ferreguetti et al. 2018). Any disturbance in the environment leads to a decrease in the diversity of insect species which serves as a warning to start conservation efforts in particular areas (Frizzas et al. 2020). The first step is to conduct a faunal diversity study to determine specific species prevalence such as flies, ants, bugs, and beetles. These species are valuable indicators that can be used to monitor climate change effects on plants and their associated species (Gaston et al. 2013). Ants may threaten some native mesofauna (Santos 2016) but their predatory nature is also helpful to kill pest species in agricultural areas (Wetterer et al. 2012).

With global environmental issues taking center stage in recent decades, researchers have been continuously working on further detection and estimation techniques for ecological species distribution (Pimm et al. 2014). Varied application of biodiversity assessments has played an extraordinary role in understanding the diversity patterns of fauna (Rix et al. 2015), the processes that shape them (Kerkhoff et al. 2014), and the conservational implications for all species (Joppa et al. 2013). The ecosystem in which succession takes place offers considerable details about flora and fauna diversity, as well as future associations between biotic and abiotic factors (Mace et al. 2012).

The distribution records and community-level data of ants have given novel insights into macroecological and evolutionary perspectives (Guenard et al. 2017). In addition, species-level dynamics can define processes or functions (Gray et al. 2018); to this end, ants can be used as a bioindicator (Woodcock et al. 2011). These are biological metrics for the estimation of environmental variations focused on ease of sampling, dominant biomass, advanced taxonomy, and environmental change sensitivity (Shahabudin 2011). Numerous studies on the temporospatial distribution of species have shed light on their diversity patterns across a variety of regions (Antweb 2019), including China (Guenard and Dunn 2012), Pakistan (Rasheed et al. 2019), and India (Bharti et al. 2016a, b).

Ants' predation, in addition to the repelling and semiochemical properties, makes them prospects for future integrated pest management strategies in agriculture (Offenberg 2014). They also mineralize nutrients, form soil aggregates, and disperse seeds (Pfeiffer et al. 2013). Ants are significant and necessary for decorous ecosystem functioning and sustainability (Del Toro et al. 2012). Given the immense ecological value of the ant fauna, this study was planned to explore ants in specific ecological regions of Faisalabad, Pakistan. The study uncovers ant prevalence and diversity and creates foundational records for the area.

MATERIALS AND METHODS

Study sites

The study was planned to determine the prevalence and diversity of Formicidae (ants) in a northern irrigated plain region of Faisalabad, Pakistan. This region has distinct ecological habitats and shows seasonal variations during the entire year. The average temperature and humidity of Faisalabad is 33.9 °C and 42%, respectively. The sample collection was done from two different stations in the year 2018-2019: Domestic and Wild habitats/areas. The ecological features of both sites are given in Table 1.

Table 1. Characteristics of study sites of Faisalabad, Pakistan

Information	Domestic	Wild
Coordinates	31.4504° N, 73.1350° E	31.4627° N, 73.1954° E
Vegetation	Areas attached with houses, plots, grasses, small vegetation	Forest area, Bank of water bodies, Grassy plots
Soil features	Sandy loam	Sandy loam

Experimental layout

Sample collection was done once a month over a period of six months. Ten pitfall traps, as well as hand sampling methods, were used to collect ant fauna, with each trap placed 10 meters apart. Pitfall jars were half-filled with 10% formalin solutions, and a few drops of detergent to remove water surface tension (Triplehorn and Johnson 2005). On each sampling day, traps were kept in place for 48 hours and fauna was collected afterward. Hand sampling took place for 2 hours in each study site on sampling days. Abiotic factors of temperature and humidity were also recorded on the day of sampling. The collected specimens of fauna were transported to the lab and washed with distilled water. Subsequently, ant species were sorted based on similar morphological characteristics and moved to vials containing a mixture of formalin and glycerin in a 70/30 ratio. Finally, identification of specimens was performed with the aid of stereomicroscope, taxonomic literature and internet resources (Antweb.com and Antwiki.com).

Statistical analysis

After the tabulation of data, the Shannon Diversity Index (Shannon and Weaver 1949) was used to determine different diversity factors (Diversity H, Richness, Evenness, and Dominance). This diversity index describes significant diversity differences between study sites, which allows us to estimate population dynamics. T-tests were performed to find the difference in species richness levels in each sampling territory. Species abundance distribution (SAD) was used to describe the commonness or rarity of species in the ecological system (McGill et al. 2007). SAD was also used to check the ranking of species within the observed data. The data were analyzed at a significance level of $\alpha = 0.05$ using various computer software (GraphPad Prism, Past3, and Minitab).

RESULTS AND DISCUSSION

A total of 759 specimens of the Formicidae family (ants) were collected for the study. This included 4 subfamilies, 9 genera, and 20 species from the Domestic area; whereas the Wild area samples consisted of 4 subfamilies, 14 genera, and 24 species. Overall, abundance was found more in the Wild area (N = 503) and less from the Domestic area (N = 256) (Table 2). The most abundantly found species from the Domestic area were *Lasius niger* (N = 32) and genus *Camponotus*, while *Formica* spp. II (N = 74) and genus *Camponotus* were recorded maximally from the Wild area (Table 3).

Table 2. Comparison of taxa in both territories (domestic and wild)

Territories	Abundance	Subfamilies	Genera	Species
Domestic	256	4	09	20
Wild	503	4	14	24

Table 3. Species composition and comparison of abundance between domestic and wild territories

Species	Domestic	Wild
Lepisiota frauenfeldi	0	8
Camponotus compressus	9	48
Camponotus confucii	0	51
Camponotus spp. I	17	0
Camponotus japonicus	0	14
Camponotus spp. II	4	6
Camponotus oblongus	7	0
Camponotus sericeus	0	6
Camponotus spp. III	26	5
Formica nigra	19	27
Formica spp. I	12	28
Formica spp. II	0	74
Lasius alienus	2	21
Lasius spp.	14	11
Lasius niger	32	20
Polyrhachis spp.	26	0
Polyrhachis hodgsoni	16	35
Plagiolepis spp.	16	41
Tapinoma spp.	0	13
Dorylus labiatus	14	22
Dorylus spp.	9	6
Lioponera longitarsus	0	12
Cardiocondyla spp.	0	3
Crematogaster spp.	6	0
Meranoplus spp.	0	9
Myrmica spp.	0	12
Monomorium longi	8	12
Monomorium spp.	5	0
Pheidole spp.	4	0
Pheidole nietneri	10	19
Total	256	503

Diversity (H) (2.885) and Margalef Richness (3.697) indices were recorded higher for the Wild habitat, while Evenness (0.828) was found higher in the Domestic habitat as compared to the Wild habitat (0.746). Dominance was documented to be higher (0.0699) in the Wild habitat (Table 4).

T-test results showed that the difference between the samples collected from the two territories is statistically significant (t = -2.223**,** $p < 0.05$) (Table 5). The SAD metric was applied to check the actual abundance and the ranks of species. For the Domestic area sampling sites, the data was statistically significant (interaction categories × species rank: $F_{5,192}$ = p < 0.001); similarly, results were significant for the Wild area (interaction categories × species rank: $F_{5,192}$ = p < 0.001) (Figure 1).

Average monthly temperature (°C), relative humidity (%), and abundance were recorded and analyzed from both areas, Domestic and Wild. The abundance of ants varied with a change in temperature and humidity; low levels of humidity and an average range of temperature favored the abundance of ants, while it became low when the temperature dropped, and the humidity levels rose. Overall, ant abundance was recorded higher from the Wild area and lower from the Domestic area (Figure 2)**.**

Table 4. Diversity indices of the two study habitats

Diversity factors	Domestic	Wild
Individuals	256	503
Dominance_D	0.0693	0.0699
Simpson_1-D	0.9306	0.9301
Shannon_H	2.807	2.885
Evenness_e^H/S	0.828	0.7461
Brillouin	2.658	2.784
Menhinick	1.25	1.07
Margalef	3.426	3.697
Equitability_J	0.937	0.9078

Table 5. Comparison of species richness between the territories using t-test

Variable means (domestic, wild)	8.53, 16.77
Pearson correlation	-0.0336
df	29
t Stat	-2.223
P-value	0.017

Discussion

The study's location, Faisalabad, is an agriculturally productive area, and considered part of the alluvial plains which reside between the Himalayan foothills and the central core of the Indian subcontinent (Saeed et al. 2018). Faisalabad only covers a part of the subcontinent's northern plain ecological zone, which has not been studied for ant prevalence and diversity since Bingham's (1903) seminal research on the ecological diversity of British India, Ceylon, and Burma. More recently, the three ant studies conducted in Pakistan did not collect samples in the irrigated plain region (Usman et al. 2017). Our study revealed a total of 30 species of ants, comprising four subfamilies. The Formicinae subfamily exhibited a vast number of species and patterns shared with other studies conducted in the Atlantic Forest biome (Suguituru et al. 2013).

Between our study sites, some of the minor differences may be attributed to habitat as each ant species prefers a specific locale. The variation in habitats, as well as biological and physical factors, exert pressure on the occurrence of fauna (Pacheco and Vasconcelos 2012). In this study, some species were more prevalent in one of the areas as compared to the other. The Formicinae subfamily generally exhibits a high diversity in food habits and nesting (Baccaro et al. 2015). Cabra-Garcıa et al. (2012) recorded a high abundance of ants in Colombia due to environmental conditions, resource availability, and variance in climatic factors. Similar to findings in our study, previous investigations of other habitats have suggested a highly diverse ant fauna (Triyogo et al. 2020). Many of those studies also indicated a high degree of species turnover in habitats, especially among significant plant physiognomies (Pacheco and Vasconcelos 2012). Predatory ants can be incredibly efficient at exterminating local arthropod species which negatively alter the environment (Wetterer et al. 2012). Given ants' sensitivity to environmental changes, differences in species diversity could occur over a period of time.

It is well established that environmental variables and the influence of biogeographic factors account for most fluctuations in species abundance. Climatic conditions impact the biodiversity of species (Garcia et al. 2014; Williams and Newbold 2020). In our study, environmental variables' effects were recorded, which showed strong control over ant fauna's diversity and abundance. The abundance of ants varied with a change in temperature and humidity. The middle level of humidity (55-60%) and an average range of temperature (30°C) favored the abundance of ant fauna, while the abundance of ants became low when the temperature dropped (11°C) and humidity levels rose (81-83%). Earlier studies have suggested that precipitation is more influential on ant diversity at high temperatures than at low temperatures (Andrew et al. 2012). This is an important consideration in our study since the samples were taken in sandy-loam areas, where the temperature at times reaches close to 50°C. For agricultural management, understanding how species' behavior varies with climate changes may be imperative to ensuring food security in the future. Since there has been no previous work done in this region on ant diversity, the study is a valuable addition to understanding this area's ecological environment.

In this study, 4 subfamilies, 15 genera and 30 species of the Formicidae family were recorded. These results were supported by Hina et al.'s (2013) research in which they found 7 species from three subfamilies in the Baluchistan region of Pakistan, but differ in the record of species such as *Camponotus*, *Formica,* and *Lasius*. Umair et al. (2012) identified 21 species and 13 genera from three subfamilies; wherein genera *Camponotus, Formica, Lasius* and *Polyrhachis* showed similarity in the occurrence of fauna to our study. India, Pakistan's neighboring country, has recorded the most abundant ant fauna in the region with 828 species of which 342 are native to the country. The large area of India contributes to this higher diversity (Bharti et al. 2016a). In Pakistan, only 104 species have been recorded; this lack of data signals a need for further research efforts (Umair et al. 2012; Bodlah et al. 2016; Rasheed et al. 2019).

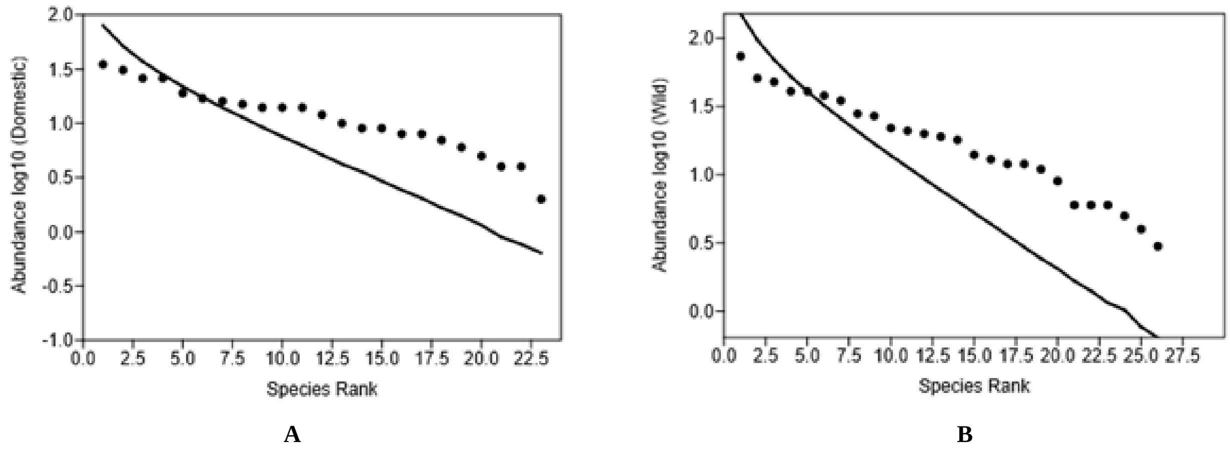

Figure 1. Species abundance distribution (SAD) showing comparative species richness; A. Domestic, and B. Wild

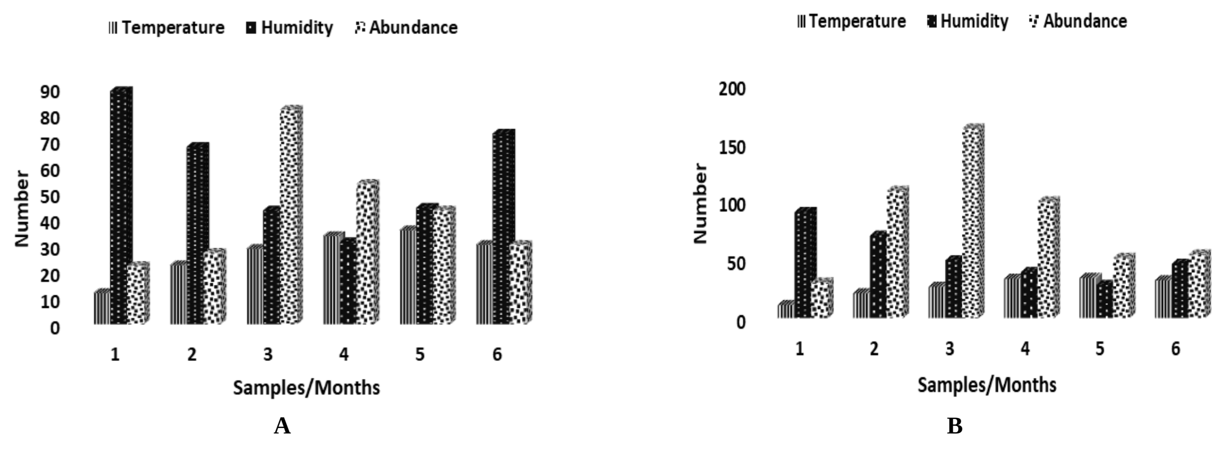

Figure 2. Occurrence of ant fauna in different range of temperature and humidity; A. Domestic, and B. Wild

In conclusion, results from our study indicate that the Formicidae family of the order Hymenoptera is very prevalent in the Northern Irrigated Plain ecological region of Pakistan with greater species richness in the Wild area. Diversity was recorded higher for the Wild habitat, while Evenness was recorded higher in the Domestic habitat. Results showed a statistically significant difference for both the Wild and Domestic habitats. The abundance of ants varied with changes in temperature and humidity. Overall, however, the temperature had a greater impact than humidity. We cannot make use of insects in an informative way until we know their precise ecological habitat. A practical, workable approach should be used to preserve current species, achieve sustainable levels of biodiversity, and prioritize key species populations to develop conservation and agricultural management strategies. Evidently, more work is needed with broad trials to unveil the rich fauna in this hitherto unexplored ecological region of the Indian subcontinent. This research not only illustrates the biodiversity of the area but also highlights the need to study this significant community of insects in Pakistan. This will be of particular interest to those in agricultural management roles who may face pressure from pest species threatening crop yields. Future studies may investigate entire ecosystems within Pakistan over time to see how species and food webs are affected by variations in global temperature or other environmental changes. This study can be helpful in the planning of conservation programs as well as provide information to farmers and researchers to initiate integrated pest management strategies in particular areas.

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