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ABUNDANCE AND DIVERSITY OF ANT TAXA IN BAHIR DAR AREA, NORTHWESTERN ETHIOPIA

Melaku Wale[1,]*and Tilahun Anteneh[2]

ABSTRACT: Species diversity and distribution of ants has not been well investigated in Ethiopia or in Bahir Dar area, Ethiopia. The objective of this study was to identify ant taxa and determine their diversity and distribution in different terrestrial and forest habitats in Bahir Dar area. Ants were collected from the ground weekly from December 2015 to November 2016 with 10 × 13 cm baited cards in 4 traps that were 7 metres apart from each. A total of 60,000 ant specimens consisting of 5 subfamilies: Formicinae, Myrmicinae, Ponerinae, Dorylinae and Dolichoderinae and 7 genera, i.e., *Lepisiota*, *Myrimicaria*, *Pheidole*, *Axinidris*, *Centromyrmex*, *Camponotus*, *Dorylus*, were recorded. Myrimicinae and Formicinae were more abundant than other subfamilies. *Lepisiota*, *Myrimicaria* and *Pheidole* were the most abundant genera. Shannon's diversity index was higher for the roadside, built up area (residential and other buildings), grass land, cultivated area and forest in descending order. Evenness was found to be between 0.52 on cement cracks to 0.75 on roadsides and built up areas, indicating medium to high evenness, i.e., there was no taxa that was particularly dominant. Populations were significantly higher during the rainy season ($F = 37.9$, $df = 51{,}356$, $p<0.0001$). The aggressive *Dorylus* was absent during the dry season, an indication that wet ground was its preference for foraging. This study was the first of its kind in the area, and can serve as a benchmark for future reference to ant taxa in the area.

Key words/phrases: Ethiopia, Formicidae, Habitat, Population Dynamics, Season.

INTRODUCTION

As human population increases rapidly, it also exerts stress upon the environment. Modern agriculture disrupts native vegetation and the natural processes. On the other hand, humans also seek to restore disturbed habitats to the original state. Environmental managers or rehabilitators use biological indicators to estimate the success of restoration efforts (Alonso and Agosti, 2011).

Invertebrates are good indicators of ecological condition because they are very sensitive to environmental change (Yoshiaki *et al.*, 2003). Even if

[1] Bahir Dar University, P.O. Box 79, Bahir Dar, Ethiopia. E-mail: melakuwale@gmail.com
[2] Ethio-Japan Preparatory School, Bahir Dar, Ethiopia
*Author to whom all correspondence should be addressed

terrestrial invertebrates are good indicators for detecting ecological changes associated with human land use systems, their huge numbers and taxonomic challenges make them less utilized in land management practices (Andersen *et al*., 2002). On the other hand, ant fauna play key role in soil fertility, in removal of organic waste and they are a major component of multi-trophic interaction (Yeo *et al*., 2011). Ants as a social group are truly ubiquitous and usually quite conspicuous (Bolton, 1994). They are ecologically important in most terrestrial biomes (Dunn *et al*., 2007) and they respond to changing environments. They are included in conservation biomonitoring and ecosystem management services because of their sensitivity to changes in land use systems and practices (Yeo *et al*., 2011). Therefore, ants have the potential to yield more meaningful biodiversity data than many other organisms, such as plants, birds, and butterflies (Dunn *et al*., 2007). Moreover, since most species of ants have stationary and perennial nests with fairly restricted foraging ranges, they have a potential role as indicators of environmental change (Wagner *et al*., 2004). Because of their potential importance, survey of ants is an important task in biodiversity and conservation efforts (Yoshiaki *et al*., 2003).

Based on their feeding guild, ant communities can be divided into two groups, i.e., arboreal and terrestrial assemblages. Arboreal ants live on trees at the canopy top (Yanoviak and Kaspari, 2000) and they differ from ground ants which usually dominate the forest floor. Arboreal ants build their nest at the tree crown and they are quite aggressive.

Sampling arboreal ants is not an easy task; fogging them from the tree canopy incurs a lot of money and other resources (Yanoviak and Kaspari, 2000). Biodiversity inventory and monitoring programs is geared towards ground ant assemblages because they are sensitive to environmental changes or disturbance than arboreal ants and they are also easier to sample (Alonso and Agosti, 2011). The fact that ants responded to SO_2 emissions from large copper and lead smelter plants in the tropics meant that they were used as tools to measure environmental change caused by industries or development projects (Andersen *et al*., 2002).

Despite several centuries of research, the global patterns of ant species diversity, individual abundance and community composition and their drivers remain poorly understood (Dunn *et al*., 2007). Recently, however, some international research teams have studied ant diversity in Ethiopia and reported the occurrence of invasive ant species namely *Lepisiota canescens* (Sorger *et al*., 2016). The objective of the current study was to determine the diversity and abundance of ant taxa in Bahir Dar area, northwestern Ethiopia, with the aim to contribute for environmental monitoring and conservation in the area.

MATERIALS AND METHODS

Study area

Bahir Dar city is the capital of the Amhara National Regional State in the Federal Democratic Republic of Ethiopia. The city is located in northwestern Ethiopia at 563 km from Addis Ababa in Northwest of Ethiopia. According to Waste Quantification and Characterization (WQC, 2010), Bahir Dar is located at 11°38′ N, and 37°10′ E on the southern shore of Lake Tana at an altitude of about 1801 m above mean sea level. The city covers an area of 16 thousand hectares (WQC, 2010).

The survey was conducted in Bahir Dar area, in northwestern Ethiopia, an area belonging to Ethiopia's ecological zone classified as mid-highlands (Temesgen Tadesse, 2007). The region is considered to be one of the few grain sources of the country with one reliable rainy season, a mono modal rainfall pattern, most of it received between June and September (Fig. 1).

The classification of the landscape was done in accordance with the Agroecological Belts of Ethiopia (Hurni, 1998). A chain of mountains and an extensive upland plateau better known as Mount Guna, 3700 m above sea level, is found at aerial distance of 74 km northeast of the study area. Mount Guna belongs to the so-called Afro Alpine zone. Tussoc grass dominates the plateau. Next is the Subalpine Zone situated between 3200–3700 m altitude. The natural vegetation there consists of *Erica arborea* and *Hypericum revolutum*. The Upper Montane Zone is situated at an altitude of 2300–3200 m consisting primarily of *Hagenia* woodland.

The Middle Montane, representing the current study area, Bahir Dar, lies between 1500 and 2300 m altitude. This zone enjoys the most pleasant weather and it is preferred settlement area of the Amhara people of Ethiopia (pers. obs.). Its optimal temperate and humid climate is the most suitable for agriculture. Within this zone natural forests are still found in lower slopes, for example the Alem Saga State Forest and Tara Gedam forest. Tree species like *Acacia abyssinica*, *Cordia africana*, *Celtis africana*, *Ficus sycomorus*, *Ficus vasta*, *Olea capensis hochstetteri* and *Cussonia holstii* occur naturally within these forests. It is naturally a zone of dry evergreen mountain forest and grassland-complex or evergreen scrub vegetation. Riverine forests along rivers and streams are common sites including

Sesbania sesban, *Mimusops kummel*, and *Combretum-Terminalia* Woodland restricted to special locations such as lava streams. Main species in those remnant vegetation patches are *Combretum molle, Terminalia brownie, Ficus sycomorus, Euphorbia abyssinica,* and *Cussonia holstii*. Bahir Dar lies at the southern shore of Lake Tana, the largest lake in Ethiopia (85 km by 66 km area). The lake suffers from sediments transported from the catchment area described above and its dominant agriculture (siltation process). Some 8.96–14.84 million tons of top soil is washed into the lake annually (Succow and Mundt, 2013). Floating mats *of Ceratophyllum demersum, Eichhornia crassipes and Nymphaea* species are common sights on the lake waters (Succow and Mundt, 2013). The most widely growing wetland plant, *Cyperus papyrus*, is the most productive one, with high potential for carbon sequestration. The study area is one of the few major food grain sources of the country. Cereals, pulses, oil crops, fruits and vegetables are widely grown (pers. obs.).

Weather data for the current study were obtained from the nearest meteorology station (Bahir Dar Station, northwest Ethiopia). According to the records of Bahir Dar Meteorology Station, during the study period, maximum temperatures were high between February and May and were low between July and September (Fig. 1). Mean monthly maximum temperatures varied from about 26°C in August to 33°C in May. Minimum temperatures were high in April and May (about 14°C) and low in December and January (about 8°C to 9°C). The peak rainy season ran from June to September and it was low for the rest of the study period.

Study design

A series of cross-sectional surveys were conducted to assess the diversity and distribution of ants in Bahir Dar district from December 2015 to November 2016. Sampling was carried out at different habitats, i.e., built-up areas (construction and residential neighbourhoods), agricultural fields, (forests, protected vegetation), under and near stones, cement cracks, roadsides and grass land areas. Forests were categorized into two conditions: forests strictly protected with no access to animals and humans and those that were free grazing areas.

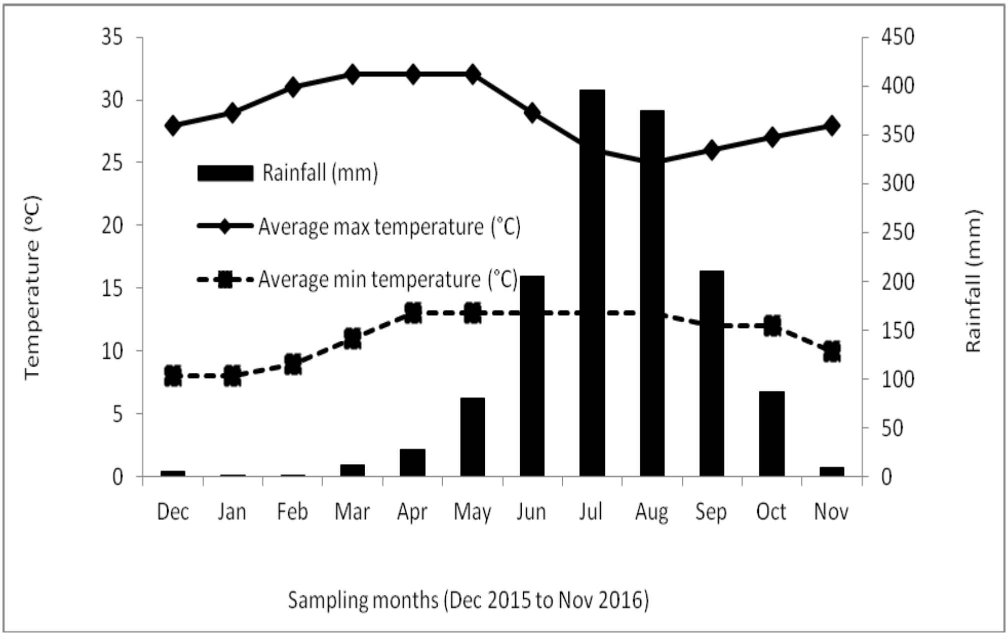

Fig. 1. Rainfall and temperature conditions in Bahir Dar area from December 2015 to November 2016.

Sampling techniques

Ants were collected from each habitat four times a month with an interval of a week between successive samplings. At each location, 10 × 13 cm cards with baits (a mixture of sugar, vegetable oil, corn syrup and meat), 7 metres apart from each other, were set up early in the morning, left there for 5 hours and collected in the afternoon. These traps were replicated four times at each habitat. All samples were transferred to a white plastic bag and later transferred to vials. Representative ants for each type were preserved in 70% ethanol for laboratory identification (Doherty, 2013). Each vial was individually sealed and labeled. Under dissecting microscope, specimens were identified to subfamily and genera levels using morphological characters or ant identification keys (Bolton, 1994; Mohamed *et al*., 2001; Yoshiaki *et al*., 2003; Schreven *et al*., 2014). Antennal club, antennal socket, clypeus, frontal lobe, compound eyes, mouth parts, occipital carina, acidopore, and waist were used for identification. A good expert (taxonomist) can identify ants without dissecting microscope once the taxonomist has been used to them (unless a new species emerges).

Data analysis

Abundance of ants of each sub family and genera and total population size (number of ants recorded per month from all habitats) were calculated. Normality test (Shapiro-Wilk) and homogeneity of variance tests (Levene's test) were undertaken before analysis of variance. Two-way Analysis of Variance was used to determine the relative abundance of ants across season, between genera and subfamilies. The taxa diversity within a habitat was calculated by using Shannon and Simpson diversity indices. The Shannon index (H′) was used to determine the diversity of the ants at different habitats.

$$H' = -\sum_{i=1}^{S} \left(\frac{n_i}{N}\right) * \ln\left(\frac{n_i}{N}\right)$$

Simpson's diversity index (S) was used to determine the evenness of different taxa in different habitats. The evenness measure changes between 0 and 1, with maximum value when all species are equally abundant, and is independent of richness.

$$S = 1 - \sum_{i=1}^{s} \frac{n_i(n_i - 1)}{N(N-1)}$$

Where, n_i = the number of genera in the i^{th} sub family,

S = number of different sub families in the sample, and

N= total number of sub families.

The value of ´S´ ranges between 0 and 1; 0 represents no diversity and 1 represents infinitive diversity.

RESULTS

Abundance of ants with respect to subfamilies and genera

A total of 119,378 ant specimens consisting of seven genera within 5 subfamilies were recorded (Table 1). The subfamilies include Formicinae, Myrmicinae, Ponerinae, Dorylinae and Dolichoderinae. More ants were recorded in the subfamilies Myrimicinae and Formicinae. In contrast, numbers were low under subfamilies Dolichoderinae and Ponerinae. In terms of genera, *Lepisiota*, *Myrimicaria* and *Pheidole* were more abundant and *Axinidris* and *Centromyrmex* were the least abundant.

Table 1. Total number of individuals recorded with respect to family and genus.

Subfamily name	Genus (under the subfamily)	Number of individuals per genus	Number of individuals (subfamily level)
Ponerinae	*Centromyrmex*	1680	1680
Dorylinae	*Dorylus*	20235	20235
Dolichoderinae	*Axinidris*	442	442
Myrimicinae	*Pheidole*	24566	56664
	Myrimicaria	32098	
Formicinae	*Lepisiota*	37602	40357
	Camponotus	2755	

Ant genera identified in different subfamilies

Two genera were recorded from subfamily Myrimicinae, i.e., *Pheidole* and *Myrimicaria*. Two forms of *Pheidole* were found: the first form had large mandibles and one pair of spines on the thorax; the minor worker was smaller than the first form. The minor worker was slightly larger than *Lepisiota*. Under the subfamily Formicinae two genera, i.e., *Lepisiota* and *Camponotus* were recorded. *Lepisiota* was small in size, widely distributed and preferred sugary food and were commonly found near homes. *Camponotus* is grouped into the larger groups (*Pheidole* major, *Dorylus* and *Centromyrmex* type 1). In subfamily Ponerinae, one genus was recorded, i.e., *Centromyrmex*. In the specimens collected two groups of *Centromyrmex* (types 1 and 2) were found. Type 1 had longer sting, larger frontal lobe, triangular mandible, relatively larger than type 2 in size, plus thinner and longer body, while type 2 had elongate-triangular mandible, shorter stinger than type 1, frontal lobes also smaller than type 1. Type 2 is larger in size than *Pheidole* minor. Type 2 which constituted 96.3% of the total *Centromyrmex* ant collection was more abundant than type 1.

Dorylus was the only genus that was identified in the subfamily Dorylinae. *Dorylus* are aggressive and attack animals and people, and when it bites a person or an animal, it cannot detach itself unless it is cut off from its neck. This happens due to the shape of the mandible, which is excavator-like with long and acute tooth. Subfamily *Dolichoderinae* had one monomorphic genus, i.e., *Axinidris*.

Ant taxa diversity and abundance in different habitats

The diversity and abundances of ant tax in different sampling habitats is indicated in Fig. 2. More subfamilies and genera were found in the cultivated, grassland and roadside areas. Number of individuals was more under stones, roadside and built up areas than in other habitats (Fig. 2c).

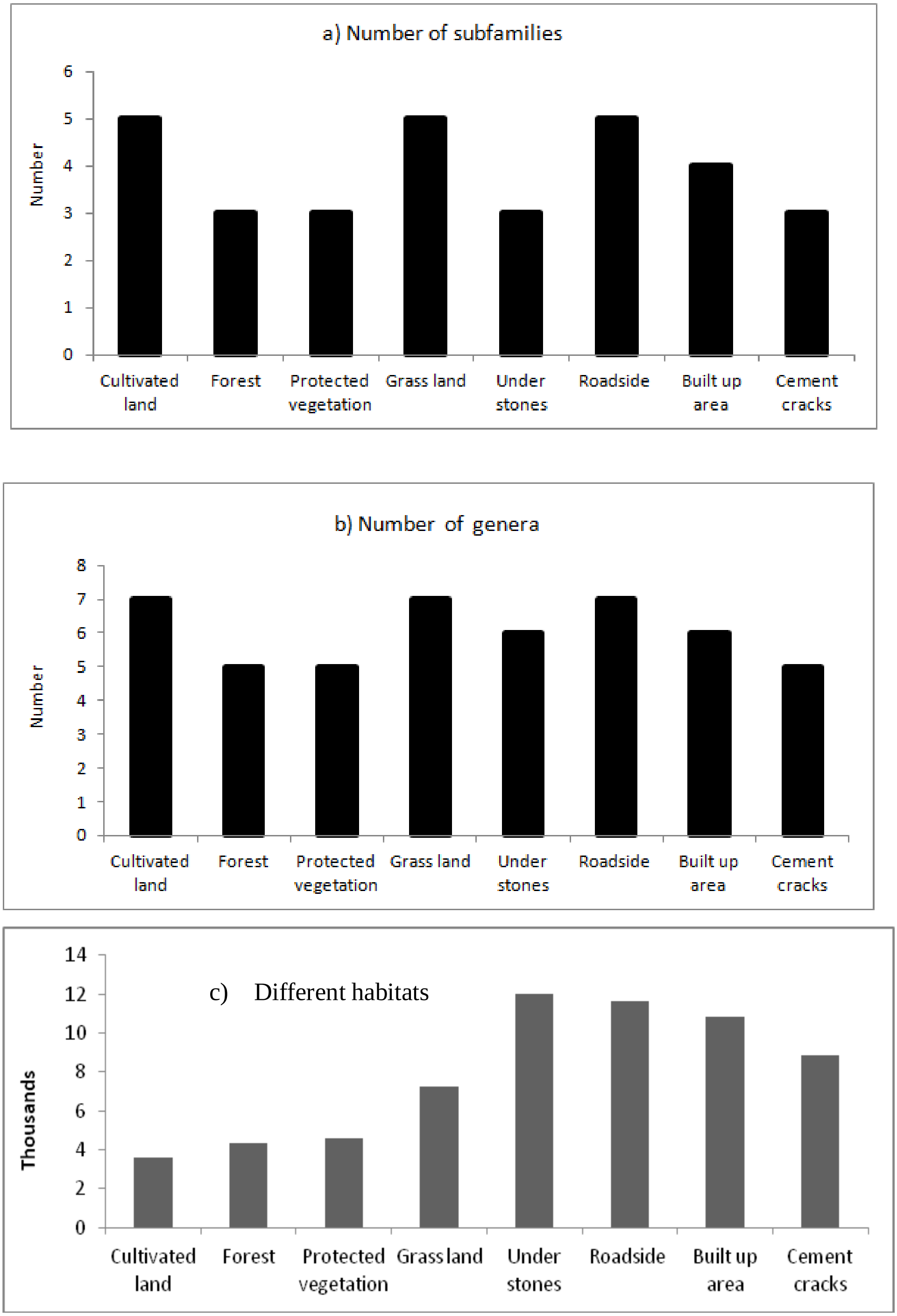

Fig. 2. Number of subfamilies, genera and abundance of ants found at different habitats in Bahir Dar area.

Shannon's diversity index showed more or less similar trend where there was more diversity at roadside, built up area, grass land, cultivated area and forest (Table 2). Evenness varied between 0.52 on cement cracks to 0.75 on roadside and built up area, indicating medium to high evenness.

Table 2. Shannon's diversity index and Simpson's index of ant taxa at different habitats.

Habitat	Number of subfamilies	Number of genera	Total number of individuals collected	H′	S
Cultivated land	5	7	3583	1.36	0.69
Forest	3	5	4319	1.33	0.70
Protected vegetation	3	5	4558	1.03	0.60
Grass land	5	7	7264	1.43	0.72
Under stones	3	6	11997	1.33	0.70
Roadsides	5	7	11665	1.50	0.75
Built up areas	4	6	10822	1.48	0.75
Cement cracks	3	5	8841	0.86	0.52

Seasonal diversity of ant taxa

A clearly mono-modal seasonal distribution of ants was observed (Fig. 3). Therefore, a conspicuous peak was observed in the three rainy months, i.e., June (25,119 ants recorded), July (26,565 recorded) and August (24,890). Thereafter, numbers steadily declined starting in September and ending in March. Numbers quickly rose again beginning from April towards the peak period (July).

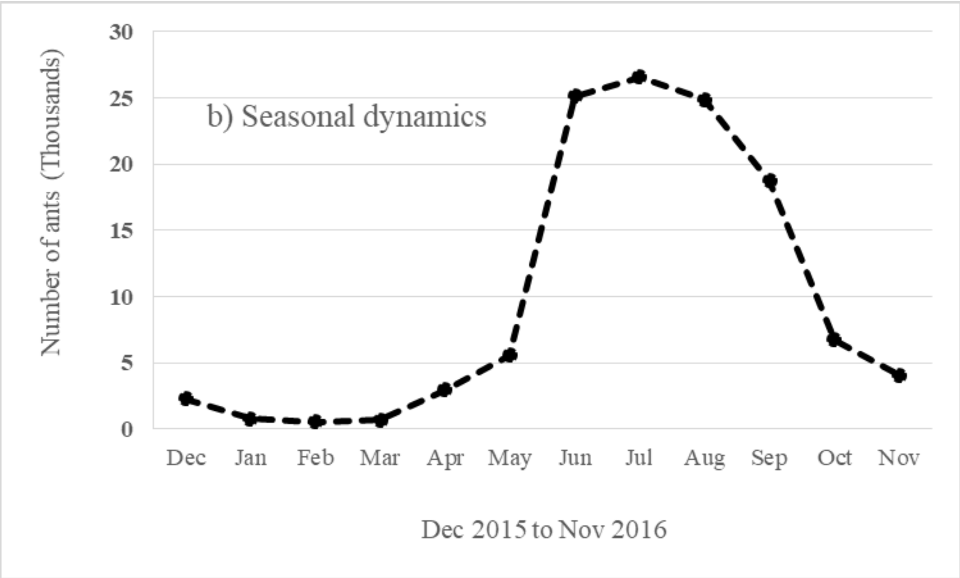

Fig. 3. Total number of individuals collected across the season in Bahir Dar area.

According to the results of the two-way analysis of variance, the seasonal abundance of ants varied significantly between sampling months and subfamilies ($F_{55,647} = 21.1$, $p<0.0001$). Numbers varied significantly between months, subfamilies and the interaction between the two was also significant (Tables 3 and 4). Example, Dorylinae were absent during the dry period and abundant during the wet period. Ponerinae and Dolichoderinae were low throughout the study period. Seasonal abundance of ants was high between June and August with a peak in July, i.e., the rainy period, and it was low during the dry period through January to March. The lowest population was recorded in February.

Table 3. Effect tests for months and subfamilies and their interaction.

Source	Number of parameters	DF	Sum of squares	F ratio	Prob>F
Month	11	7	754872.0	9.11	<0.0001
Subfamily	4	2	857115.3	36.22	<0.0001
Month*Subfamily	44	40	1892394.2	4.00	<0.0001

Dorylinae (*Dorylus*) was not observed from January to March (Fig. 4) but it was abundant between April and October. Number of *Dolichoderinae* and *Ponerinae* was very low all year round (during the study period). On the other hand, season had profound effect on the number of individuals of families of *Dorylinae*, *Myrimicinae* and *Formicinae*. Their numbers were low during the dry season (lower than 200 per month), which dramatically increased during the wet season (up to a high of 637). In fact, numbers gradually increased beginning from April and peaked in July. However, numbers were significantly higher in June and July than in April and May (Fig. 4). Similarly, abundance of ants of the different genera significantly varied across the season ($F_{51, 356} = 37.9$, $p<0.05$). Ant population of the three genera, i.e., *Centromyrmex*, *Axinidris* and *Camponotus* was independent of seasonal influence.

Table 4. Abundance of individuals under each subfamily across the season in Bahir Dar area.

Sub family	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Dorylinae	215.5c-k	0n	0n	0n	187.0c-k	207.2d-k	404.6a-e	637.0a	435.7a-d	507.3ab	441.1a-e	208.3d-k
Myrimicinae	47.5k	19.3k	13.6k	21.0k	91.5i-k	123.0i-k	278.3e-g	444.2a-c	279.9d-f	338.7b-e	90.5i-k	187.0i-k
Formicinae	47.6k	31.8k	22.0k	27.1k	81.1i-k	110.5i-k	203.1f-i	269.9e-h	195.2f-j	206.7f-j	81.2jk	101.9i-k
Ponerinae	18.7f-k	11.4i-k	5.8i-k	4.0h-k	10.3h-k	14.5i-k	30.4k	13.3k	30.2k	9.8k	27.3i-k	14.7f-k
Dolichoderinae	6.7h-k	4.0f-k	5.5f-k	4.0f-k	12.7g-k	13.3i-k	19.2i-k	19.2i-k	5.6i-k	6.5f-k	7.2i-k	13.3g-k

Means followed by the same letter(s) are not significantly different from each other according to Tukey HSD test at $\alpha=0.05$.

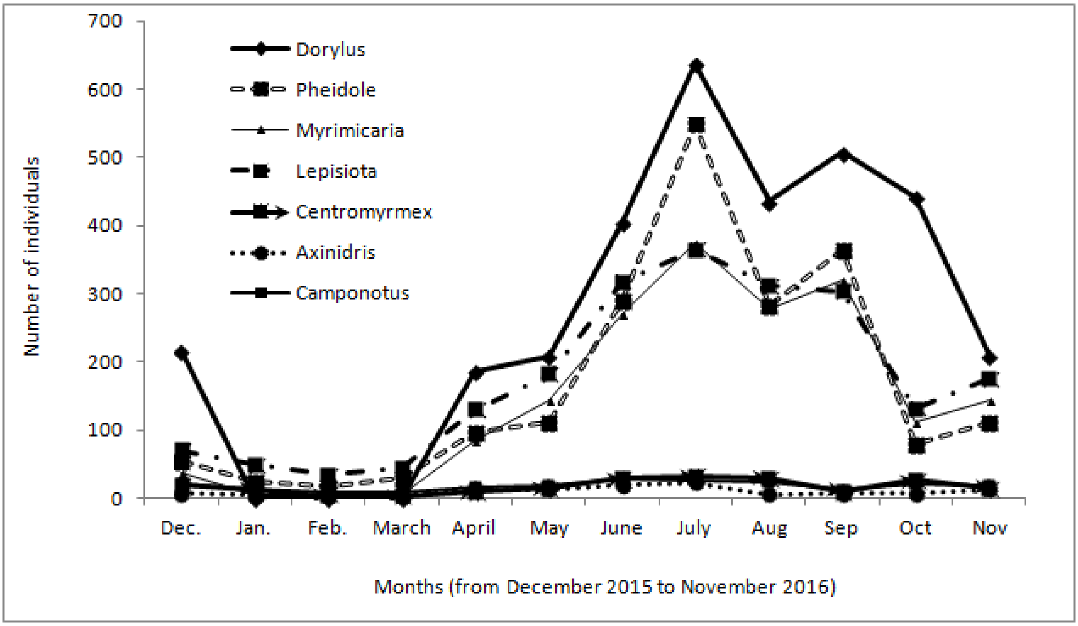

Fig. 4. Seasonal population dynamics of different ant genera in Bahir Dar area of Ethiopia (mean number per trap).

DISCUSSION

In the present study, five subfamilies were collected and identified. The most predominant families were Formicinae, Myrmicinae, Ponerinae, Dorylinae and Dolichoderinae. Earlier studies in different African countries indicated that the most abundant ant subfamilies in the world as well as in Africa are the same subfamilies Myrimicinae followed by Formicinae (Bolton, 1994; Garcia *et al*., 2013). Izwan and Amirrudin (2014) reported Formicinae as more abundant than Myrmicinae. On the other hand, Brady and Ward (2005) reported that Dorylinae was the predominant ant taxa in tropical Africa.

One of the two genera under subfamily Myrimicinae, the *Pheidole* was found to be dimorphic. Generally, African *Pheidole* (African big-headed ants) are dimorphic, i.e., *Pheidole* major and *Pheidole* minor workers (Doherty, 2013). Subfamily Formicinae included genus *Lepisiota* which was widely distributed. A research team working in Ethiopia recently reported that *Lepisiota* was potentially a global invasive ant species (Sorger *et al*., 2016). They reported that *Lepisiota* colonies were found at a span of 38 km and had a potential to invade the world. On the other hand, because *Camponotus* workers are produced at a slow rate (Hansen *et al*., 2005), their number is expected to be lower than *Lepisiota*. Family *Dorylinae* was found to be a single genus subfamily. Schoning *et al*. (2008) reported the same condition.

More diversity and population abundance is expected from undisturbed areas (forest, protected areas, grasslands). This condition was not observed in the present study. This might be due to forest fragmentation affecting the structure of ground-dwelling ant communities (Agosti *et al*., 2000). In the study area, the forests and protected areas were fragmented and they were recently established habitats. Fragmentation may result from growing urban neighborhood and poor urban planning. Forests do not necessarily mean that they are protected. They may be areas where animals graze and people harvest forest products. Virgin forests usually consist of most flora and fauna compared to the disturbed forest (Izwan and Amirrudin, 2014). Protected areas may be fenced, but people cut grass for animal feed and mostly they are located near to areas of human activity, so they are not completely undisturbed. These habitats were covered with vegetation. The method used in this study was ground trapping and, therefore, arboreal ants were not included in the samples. Other factors might have also contributed for the observed difference. Further study may be necessary to identify other potential confounding factors involved. For example, Dejean *et al*. (1997) argued that the presence of plant species such as mango that produce nectar and honey, promote ant activity.

Ants feed on meats, dairy products, pastries, fruits, animal fats, and vegetable oils, as well as dead insects (Dunn, 2014). Therefore, built up areas and roadsides are areas where people leave food scraps and other organic materials and these waste materials can serve as a source of food for ants. Many of the roadsides included in the study were built near to the built up areas and some were covered by vegetation and ants could have preferred these areas for feeding and nesting. This implies also that disturbed habitats such as roadsides and residential areas could serve as sanctuary for ants and increase ant diversity. However, according to diversity indices, there was no habitat that had the greatest number of subfamilies and genera, which meant that each habitat appeared to be proportionally represented.

Ant taxa varied with season as a result of changes in weather condition and food and other resources. Weather conditions such as rainfall, humidity and temperature affected the occurrence of ants (Lu *et al*., 2012; Lutinski *et al*., 2013; Izwan and Amirrudin, 2014). The same thing was observed in this study where populations were low during the dry season and high during the wet season. The best example in the current study was Dorylinae (*Dorylus*), which was not observed during the dry season, i.e., from January to March. This was because *Dorylus* is a predatory species preying upon insects and other ants. Its foraging activity is severely limited because of diminishing population of other insects of prey during the dry season (Brady *et al*., 2014). All known species of *Dorylus* usually nest and perform their mass raids in the soil stratum, and only occasionally above ground (Liu *et al*., 2015). Dorylinae were plenty during the wet season and absent during the dry season. They march in groups following trails. African *Dorylus* ants have large colony sizes, nomadic behaviour, mass foraging, and strong ecological impacts on communities. They do not use individual scouts to locate food, as do most other ants; rather, they send out swarms of up to several hundred thousand workers in mass to kill prey items and transport them back to their colonies (Brady *et al*., 2014). In contrast to other ants, *Dorylus* appears occasionally. Numbers increased exponentially in June and July. Season had a profound impact on the number of individuals of other genera including *Dorylus*, *Pheidole*, *Myrimicaria* and *Lepisiota*. Numbers were higher between April and July. Increasing rainfall promotes a wider distribution and richness of ants (Heller *et al*., 2007). Because ants are poikilotherms, they must be very sensitive to small changes in temperature (Dostal *et al.*, 2004). According to Lu *et al.* (2012), the number of foraging worker ants is positively correlated with monthly rainfall, monthly mean temperature, monthly mean minimum temperature, monthly mean maximum temperature and monthly mean minimum relative humidity. In contrast, drought greatly increased the rate of mortality of young ants.

CONCLUSION

The data gathered revealed that ant diversity and abundance varied with season (weather condition) and habitat. The scale of diversity may indicate the degree of environmental degradation. Future studies should focus on other factors that play some role on the diversity of ants. In terms of abundance, some of the genera, i.e., *Axinidris*, *Camponotus* and *Centromyrmex* were threatened (pushed towards extinction), while *Lepisiota*, *Myrimicaria* and *Pheidole* were successfully exploiting their habitats. *Dorylus* was also successful because it aggressively defended its territory.

In view of the rapid habitat destruction in Ethiopia, taxonomic studies of ants is urgently required on a broader scale so that conservation schemes may be launched (such as maintaining refuge habitats). With new development projects everywhere, including intensive agriculture, it is likely that the number of ant taxa will continue to decline and disappear, so investigation and intervention/conservation is necessary.

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Conflict of interest and research ethics

Both authors declare that there is no conflict of interest with regard to this study and its publication.

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