ANT DIVERSITY ALONG AN ELEVATIONAL GRADIENT IN CHAMPADEVI HILL, CENTRAL NEPAL

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Kirtipur, Kathmandu
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DECLARATION

I hereby declare that the work presented in this thesis has been done by myself and has not been submitted elsewhere for the award of any degree. All sources of information have been specifically acknowledged by reference to the author(s) or institution(s).

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RECOMMENDATION

This is to recommend that the thesis entitled **"Ant Diversity along an Elevational gradient in Champadevi Hill, Central Nepal"** has been carried out by Mr. Prakash Raj Pokhrel for partial fulfillment of Master's Degree of Science in Zoology with Special paper Entomology. This is his original work and has been carried out under my supervision. To the best of my knowledge, this work has not been submitted for any other degree in any institution.

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LETTER OF APPROVAL

On the recommendation of supervisor Mr. Indra Prasad Subedi, Lecturer, Central Department of Zoology, Tribhuvan University, this thesis submitted by Mr. Prakash Raj Pokhrel entitled **"Ant Diversity along an Elevational gradient in Champadevi Hill, Central Nepal"** is approved for the examination in partial fulfillment of the requirement for Master's Degree of Science in Zoology with special paper in Entomology.

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LIST OF ABBREVIATIONS

Abbreviated Forms	Detail of Abbreviations
asl	above sea level
CCA	Canonical Correspondence Analysis
GPS	Global Positioning System
GLM	Generalized linear model
ha	hectares
NARC	Nepal Agricultural Research Council
NTFPs	Non-Timber Forest Products
MDE	Mid-domain effect
Spp	More species of same genus
Sp	Single species
sq	Squares
Reg	Registration

ABSTRACT

Nepal is characterised by high floral and faunal diversity but there are limited studies about ants. The present study is aimed at exploring the ant diversity along an elevational gradient (from 1450 m to 2452 m) in the north and south slopes of Champadevi hill, central Nepal. Ant samples were collected by using pitfall traps and all-out-search methods from spring to autumn in 2017. To find the determinant relationship between ant species richness and environmental variables (elevation, seasons, aspect, disturbance and vegetation canopy), a generalized linear model (GLM) with Poisson distribution and log link function was used. Multivariate tests for the composition of ant communities were carried using a unimodal technique known as Canonical Correspondence Analysis (CCA). Six subfamilies and 33 genera were recorded from the study. Species richness decreased with increasing elevation. The species richness was maximum during spring season (n=12) than in autumn season (n=5) and it was higher in the northern aspect (n=29) than the southern aspect (n=25). Ant composition was affected by elevation (p=0.004), seasons (p=0.002) and aspect (p=0.002). Disturbance (p=0.054) and canopy cover (p=0.180) do not show a significant effect on composition. *Amblyopone* and *Ponera* were found as new genera to Nepal. The high diversity of ants in our study area showed that the systematic study could lead to the recording of more species in Nepal.

1. INTRODUCTION

1.1. Background

Ants (Hymenoptera: Formicidae) are small-sized invertebrate ranging from 0.75 to 52 mm in size (Holldobler and Wilson 1990). They are highly evolved Hymenopterans showing high polymorphism having high-level interactive lives communicating with each other to survive and form colonies. The size of colonies vary and each colony mostly of sterile, wingless females; workers, some fertile males; drones and one or more fertile females; queens. Ants contribute a divergent group of insects to the terrestrial ecosystem as they are symbiotic in nature and have significant roles in both floral and faunal ecosystems (Watanasit et al. 2000). Moreover, they contribute to enrich soil nutrients (Lyford 1963) and often considered as indicators of pollution as they respond rapidly to the changing environment (Alonso 2000, Andersen 1990, Kaspari and Majer 2000), act as model organisms for measuring biodiversity (Madden and Fox 1997, Majer and Nichols 1998).

Ants are found in diverse habitats such as leaf litter, tree barks, soil and tree logs (Holldobler and Wilson 1990) and form 15–25% of the animal biomass (Schultz 2000). Ants perform several significant functional roles, as predators of other arthropods whereas sometimes behaving as destructors in nature of being serious herbivores (Holldobler and Wilson 1990, Way and Khoo 1992, Lasalle and Gauld 1993). Besides this, they are also beneficial to humankind as they have a role in biological control of pests (Way and Khoo 1992).

1.2. Diversity of ants

Ants show howling diversity, teemingness and dominance in biomass in almost every habitat throughout the world. They are abundant in terrestrial ecosystems due to a wide variety of feeding habits, nesting sites and interactions with organisms from different trophic levels (Kaspari 2000). Erwin (1989) recorded 69% ants out of total insect specimens collected by fogging the forest canopy at Peru. Watt et al. (2002) recorded 111 species from leaf litter in Cameroon. Fisher (2004) recorded 56 genera 310 species in Mount Doudou in South-Western Gabon. Lapolla et al. (2007) studied Leaf litter ant diversity in Guyana and collected a total of 230 species of 44 genera. Bharti (2008) listed 202 species of ants from the Himalayan region. Malsch et al. (2008) collected 376 morphospecies, belonging to 65 genera in an evergreen tropical rain forest of Mount Kinabalu, Sabah, Borneo. Noor and Amirrudin (2014) recorded 18 genera and 33 species in Krau wildlife reserve, Pahang, Malaysia. García-Martínez et al. (2015) recorded 34 genera and 89 species in Veracruz, Mexico. In the Western Ghats, India, Gadagkar et al. (1993) recorded 31 genera and 120 species; Narendra et al. (2010) collected 30 genera and 84 species.

Ants contribute significantly to local biodiversity. Wilson (1987) recorded 26 genera with 43 species from a single tree in Peru; Harada and Adis (1997) recorded 82 species on a single tree in Brazil; Stork (1991) recorded 98 species from 10 trees in Borneo; Floren and Linsenmaier (1997) recorded 192 species from 19 trees in Sabah, Malaysia; Ryder Wilkie et al. (2010) collected 489 ant species from 0.16 sq. km in Ecuador; Agosti et al.(1994) reported 104 species from 20 sq. min Malaysia; Andersen and Clay (1996) recorded 248 species from 18 sq. km in Australia; Andersen (1990) reported 105 species from 0.1 ha mallee plot work in north-western Victoria, 100 species from a 0.05 ha plot in tropical savanna; Talbot (1975) recorded 87 species from 5.6 sq. km area in Michigan. They constitute up to 15% of the total animal biomass in a Central Amazonian rainforest (Fittkau and Klinge 1973).

Elevation gradient related studies of ants explore the ant diversity as well as make a significant effort on natural resource conservation of the terrestrial ecosystem (Samson et al. 1997). Elevation and slope were significant predictors of species richness of various genera of ants (Ryder Wilkie et al. 2010). Two commonly observed patterns of species richness along elevation gradient include decreasing pattern (Olson 1994, Rahbek 1995, Rosenzweig 1995, Lomolino 2001, Sabu et al. 2008, Machac et al. 2010) or mid-elevation peaks (Hutchinson 1959, Preston 1962a, 1962b, Connell and Orians 1964, MacArthur 1969, Brown and Lomolino 1998, Sanders 2002). Ants were observed up to 4800 m in the Himalayas (Weber 1943). Climatic, biological, geographical and historical factors have been suggested as causes of variation in species richness along an elevation (Rahbek 1995, Rosenzweig 1995, Lomolino 2001, Sabu et al. 2008, Machac et al. 2010). The number of species declines with increasing latitude, altitude and aridity (Fowler and Claver 1991, Farji-Brener and Rug-giero 1994, Samson et al. 1997). Temperature, precipitation, thermal energy (Rahbek 1995, Bailey et al. 2004, Sanders et al. 2007, Barry 2008, Malsch et al. 2008, Szewczyk and

McCain 2016), light level, slope, vegetation (Robinson et al. 2003) and food resources (Watanasit et al. 2000) could have both direct and indirect effects on ant diversity along elevation. The physiological stress of extreme elevation could limit species distributions (Ricklefs and Latham 1993). Fellowes (1996) observed most tropical taxa were confined to lower elevations in Hong Kong. Brown (1973) suggested that the reduction in ant diversity at higher elevations is the result of lower levels of radiant heat. Kumar and O‟ Donnell (2009) revealed that army ants which forage above ground may be restricted to forested areas due to a thermal tolerance threshold which differs with elevation.

1.3. Status of ants in Nepal

Very little is known about the ants of Nepal. The ant species first recorded from Nepal are *Myrmica* and *Aphaenogaster* (Forel 1906). Menozzi (1939) included Nepal Himalaya in his Taxonomic key for the Himalayan *Myrmica*. Collingwood (1970) provided the list of 34 species of Nepalese ants with two endemic species within the elevation of 850 m to 4500 m. Elmes and Radchenko (2009) recorded two new *Myrmica* species viz. *weberi* and *alperti* from Makalu Barun National Park. Thapa (2015) enlisted 52 species of 29 genera. *Myrmica* is the most speciose genus of ants in Nepal (Subedi and Budha 2019). Neupane and Subedi (2018) studied ant diversity in Muhan Pokhari, Shivapuri-Nagarjun National Park and recorded 16 genera from five subfamilies. Adhikari (2016) reported 30 genera belonging to 7 subfamilies from Lahachowk, Kaski. Subedi et al. (2019) listed 121 valid extant species of ants under 49 genera and eight subfamilies among the 13804 species belonging to 337 genera and 17 subfamilies found globally (Bolton 2020). As per the recent classification, Myrmicinae is the largest subfamily with 192 genera followed by Formicinae with 83 genera and Ponerinae with 61 genera in the world (Ward 2020). Amblyoponinae, Dolichoderinae, Dorylinae, Formicinae, Leptanillinae, Myrmicinae, Ponerinae, Pseudomyrmecinae are the eight subfamilies that are reported from Nepal (Bharti and Subedi 2020). Among these, Myrmicinae is the largest subfamily which comprises of 41.37% ant species of genera *Myrmica, Strumigenys, Meranoplus* and *Pheidole* having more species followed by sub-family Formicinae which comprises of 20.68% ant species with genera *Formica, Polyrhachis, Camponotus* and *Prenolepis* having more species (Bharti and Subedi 2020).

Many species could be captured using various sampling methods varying in their efficiency and selectivity in capturing (Bestelmeyer et al. 2000, Fisher 1999, Olson 1991). Ants are abundant in different localities and are relatively easy to collect in a standardized way (Holldobler and Wilson 1990, Agosti et al. 2000). The systematic study could lead to the recording of more species. Knowing this all, the present study, therefore, aims to explore ant diversity along an elevational gradient using different techniques.

1.4. Objectives of the study

1.4.1. General objective

To explore the ant diversity along an elevational gradient in Champadevi Hill, Central Nepal.

1.4.2. Specific objectives

a) To examine the species richness and composition of ant genera in the Champadevi Hill.

b) To relate the species diversity and composition of ant species with different environmental factors (elevation, aspect, season, canopy cover and disturbance) along an elevational gradient in Champadevi Hill.

1.5. Rationale of the study

Ants are important organisms for measuring and monitoring biodiversity. They are abundant and dominant in ecological systems as a predator and as a symbiotic organism for different flora and fauna. Ants are relatively easy to collect, diverse even in a small habitat and easily identifiable (Holldobler and Wilson 1990, Agosti et al.2000). Since most ant species are stationary and have a perennial nest with a restricted foraging range, these are also useful as indicators of environmental conditions (Peck et al.1998, Hashimoto et al. 2001, Andersen et al. 2002). Human activities in natural ecosystems result in fragmentation of ecosystems and biodiversity loss. Thus, it is important to protect ant diversity. Various extensive researches on different ant species could make a significant effort on natural resources conservation. The research on diversity and distribution patterns of ants has not been carried out in Champadevi hill, Central Nepal.

The present study generates some valuable information about ant diversity and help in their protection.

2. LITERATURE REVIEW

Elevation gradient studies with different organisms date back to the origin of biogeography (Shodhganga 2019). Modern research contributions are important for developing a more general theory of species diversity.

Ants were observed along the elevation ranging from 0 to 4800 m asl (above sea level) (Subedi and Budha 2020). According to Hutchinson (1959), MacArthur (1969), Brown and Lomolino (1998) and Sanders (2002), species richness decreases uniformly with elevation or richness increases at mid-elevations. About half of research shows mid elevation peaks and about one fourth shows decreasing patterns of altitudinal species richness (Subedi and Budha 2020). In Hong Kong, Fellowes (1996) analyzed the forest dependence of local ant species and their elevational ranges and noted that most tropical taxa were confined to lower elevations (below about 500 m) locally. Some forest-dependent taxa are confined to the best and most continuously-forested parts of Hong Kong, such as the northern Tai Mo Shan forests and Shing Mun. Similarly, Samson et al. (1997) surveyed ant communities along an elevational gradient in the Philippines. They had their research extending from 250 m (dipterocarp forest) to 1750 m (mossy forest) and observed very few ants at higher elevations in the tropics.

Furthermore, Fisher (1999) studied ant diversity patterns along an elevational gradient in Madagascar and RNI d"Andringitra and gave a conclusion that species richness is peaked at mid-elevation and it could be the result of the mixing of two distinct, lower and montane forest ant assemblages. Xu Zheng et al. (2001) evaluated ant communities and their species diversity with altitudinal zonation on the west and east slope of Gaoligongshan Mountain in China. They observed that with an increase in altitude, the number of dominant species increased at the north and north-middle section, but decreased at south section. Araujo and Fernandes (2003) examined the distribution of ants along altitude gradients from 800 m to 1500 m in southeastern Brazil. They found that species richness of collected ants on vegetation and soil increased with decreasing elevation, this pattern was found for ants collected on the ground in both mesic and xeric habitats. Sanders et al. (2003) analyzed the patterns of ant species richness along elevational gradients in an arid ecosystem. They observed that ant species richness increased linearly with elevation along two transects and peaked at mid-elevation along a third transect and suggested that patterns of species richness based on data from single transect may not generalize to larger spatial scales. Nogues-Bravo et al. (2008) estimated the scale effects and human impact on the elevational species richness gradients. They used an extensive data set comprising 400,000 records covering 3,046 species of vascular plants, lichens and bryophytes. The relationship between species richness and altitude varied greatly with a scale of extent. When the entire elevational gradient was surveyed, the pattern was hump-shaped, changing progressively to a monotonically decreasing pattern as the scale of extent diminished.

Zelikova and Breed (2008) assessed seed dispersal along an extensive elevational gradient (256–2025 m) in Great Smoky Mountains National Park, USA and concluded that seed removal decreases with elevation, but seed dispersal distance was not dependent on elevation. According to the study, the most important variables predicting seed removals were average annual temperature and the abundance of *Aphaenogaster rudis* both of which varied along the elevational gradient. Longino and Colwell (2011) worked out density compensation, species composition, and richness of ants on a neotropical elevational gradient by sampling seven sites ranging from 50 m to 2000 m. They observed that worker density and microsite occupancy were high and relatively constant from 50 m to 1500 m and then abruptly dropped to near zero at 2000 m.

Also, Bernstein (1979) investigated the species diversity and diet in ant communities and found it to be relatively constant, regardless of changes in elevation or species diversity. Gadagkar et al. (1993) studied ant species richness and diversity in some selected localities in western ghats, India by sampling methods usings traps and all-out-search method and found use of trapping method more successful (six subfamilies, 31 genera and 120 species) than all-out-search method (six subfamilies, 27 genera and 101 species). Yamane and Hashimoto (1999) estimated abundance and diversity of ants concluding that a combination of various sampling methods produce better results in the evaluation of ant species. In addition, Fisher (2004) employed many methods for collecting ants, including leaf litter sifting, sweeping, yellow pan traps, handpicking etc. to evaluate the diversity pattern of ants in Mount Doudou in South-Western Gabon. During this survey, he recorded a total of 310 species in 56 genera; the highest species richness of ants recorded in Africa till to date.

Likewise, in Western Ghats, India, Basu (1997) recorded 29 species in spring and 13 species in late autumn. El Keroumi et al. (2012) recorded 13 species, seven genera in

Argan forest, Lahssinate, Morocco. They recorded higher abundance and richness in the spring and summer seasons than autumn. Sanders et al. (2007) tried to enumerate the factors that shape elevational diversity gradients in ants. The results indicated that warmer sites support more species as they support more individuals, thereby reducing the probability of local extinction. Bharti at al. (2009) analyzed seasonal patterns of ants in five seasons in the Punjab Shivalik range of Northwest Himalaya using various collection methods like Pitfall traps, Winkler's, Fish bait and Hand picking. They reported forty species belonging to 8 subfamilies for seasonal patterns and subfamily Myrmicinae was found to be the dominant subfamily. Geraghty et al. (2007) evaluated the body size, colony size and range size in ants along elevational and latitudinal gradients of eastern North America to check the effect of Bergmann's rule (size of an organism often increases with latitude and elevation) and concluded that their results do not support Bergmann's rule in ants but shows species that are able to tolerate broad climatic conditions have the largest ranges.

In addition, Collingwood (1970) examined Formicidae collected from Nepal during the 1961 expedition of prof. Dr. Janetschek in the course of the Research scheme Nepal. He found 34 species of Nepal. Out of them, 12 were distributed all over Himalayan area, 12 from eastern Himalayan and 12 from western Himalayan and two species were endemic to Nepal. Bruhl et al. (1998) investigated the stratification of ants in a primary rainforest in Sabah, Borneo. They observed dominance of Myrmicinae (39.9%) followed by Formicinae (31.5%), Ponerinae (11.5%) and Dolichoderinae (10.2%). Also, in 1999, they worked on the altitudinal distribution of leaf litter ants along a transect in the primary rainforest on Mount Kinabalu. The ant fauna along the gradients included 283 species representing 55 genera. They made sampling at different altitudes (560, 800, 1130, 1360, 1740, 1930,2025, 2300, 2600 m asl). In their study, the number of ant species decreased exponentially without evidence of a peak in species richness at mid-elevation.

Gunsalam (1998) collected about 71 morphospecies of ants belonging to 7 subfamilies during a preliminary survey and assessment of ant fauna of Borneo, Kelabit Highlands Sarawak. His findings show that ant fauna of this region has a mixture of ants found in lowland and highland areas. Watt et al.(2002) studied diversity and abundance of ants in relation to forest disturbance and plantation establishment in southern Cameroon and recorded 97 species from the canopy and 111 species from leaf litter and concluded more species occurred in a partial manual clearance plot than complete clearance plot. Lapolla et al. (2007) studied leaf litter ant diversity in Guyana and collected a total of 230 species from 44 genera. Bharti (2008) studied the altitudinal diversity of ants in the Himalayan region and recorded 202 species. Out of them, 115 ant species reach up to or cross an altitude of 2000 m above mean sea level and 71 were endemic. Furthermore, Bharti and Sharma (2009) carried preliminary investigations on diversity and abundance of ants along an elevational gradient in Jammu-Kashmir Himalaya. They found that the subfamily Myrmicinae is the most abundant (66%), followed by Formicinae 26.81%, Ponerinae 4.84% and Dolichoderinae 2.35%.

Ryder Wilkie et al. (2010) comprehensively surveyed species diversity and distribution patterns of the Ants of Amazonian Ecuador using canopy fogging, pitfall trap, hand collection method, mini Winkler device and subterranean probes and found a total of 489 ant species comprising 64 genera and nine subfamilies from the sample collected in only 0.16sq. km. Narendra et al. (2010) analyzed the structure of ant assemblages in Western Ghats, India and worked out the role of habitat disturbance and introduced species. They sampled 84 species representing 30 genera from 5 subfamilies. In their study, Myrmicinae was most widely represented with 44 species and 11 genera, genus *Monomorium* was most rich, represented by 12 species and genus Pheidole was most abundant followed by *Camponotus compressus* and *Diacamma rugosum* was most frequently occurring species.

In the same manner, Rahbek (1995) while studying the elevational gradients of species richness emphasized variation in steepness, geological perturbations, alterations of precipitation patterns etc. are some of the factors that determine the species richness in altitude. Robinson et al. (2003) probed wood ant (*Formica lugubris*) population in Upper Dearne Woodlands, to investigate the relationship between ant activity and factors such as light, level, slope and vegetation. Grytnes and McCain (2007) in their article on elevational trends in biodiversity pointed out that most commonly observed patterns are: decreasing richness with increasing elevation and a humped pattern with a richness peak at intermediate elevations and concluded that, many factors might be important in shaping the richness trends, including productivity/energy, mid-domain effect (MDE), source-sink dynamics, species-area relationships, heterogeneity and history. Malsch et al. (2008) investigated the factors responsible for the declining ant species richness with increasing elevation in an evergreen tropical rain forest of Mount Kinabalu, Sabah, Borneo. They collected 376 morphospecies, belonging to 65 genera and 8 subfamilies.

They observed that a decline in species richness is significantly correlated with a decline in temperature.

Sabu et al. (2008) estimated the diversity of forest litter inhabiting ants along elevations in the Wayanad region of the Western Ghats. According to their research, abiotic factors such as litter temperature, humidity, litter depth, rainfall and slope of the terrain were found to influence the abundance and elevational distribution of litter ants and concluded that, ant species richness increased from 300 m to 1000 m and subsequently decreased, recording a hump-shaped peak at mid-elevations. 29 ant species belonging to 18 genera under 6 subfamilies were recorded during the study. Kumar and O‟ Donnell (2009) quantified the foraging rates of above ground and underground foraging army ants along an elevational gradient from 1090 m to 1540 m and revealed that army ants which forage above ground may be restricted to forested areas due to a thermal tolerance threshold, but get released from this limitation at higher elevations. Also, underground foraging permits some army ants to persist within modified landscapes.

Schonberg et al. (2004) compared the arboreal ant species richness in primary forest, secondary forest and pasture habitat of a tropical montane landscape in a Neotropical cloud forest landscape. A total of 21 species were collected from primary forest, 20 from pasture habitat and only 9 from the secondary forest using canopy fogging method. This study has implications for the conservation of tropical montane habitats in two ways. First, arboreal ant species density is reduced if the secondary forest replaces primary forest, which increases the chances of extinction among rare species. Second, pasture trees may serve as repositories of primary forest ant communities due to similar tree structure. Anu and Sabu (2006) analyzed leaf litter ants in the Wayanad region of Western Ghats and collected 22 species from 16 genera. Subfamily Formicinae was highly speciose in evergreen forests; Aenictinaewas present only in deciduous forest and Ponerinae was less speciose in shola forests in comparison to their high speciosity in evergreen and deciduous forests in their research.

Elmes and Radchenko (2009) describe two new species *Myrmica weberi* and *M. alperti* from the Makalu Barun National Park, Nepal. Machac et al. (2010) explored the elevational gradient in assessing the phylogenetic structure of ant communities. They revealed interplay of biotic and abiotic constraints on diversity and observed that ant species density is positively related to temperature, so at higher elevations (in cooler conditions), there are fewer species than in warmer, lower elevation sites. Chavhan and Pawar (2011) reported thirty four species, twenty genera in and around Amravati city of Maharashtra, India. They reported subfamily Myrmicinae with 21 species, 11 genera, subfamily Formicinae with 7 species, 4 genera, Ponerinae with 3 species, 2 genera, subfamily Dolichoderinae with 2 species, 2 genera of and Pseudomyrmicinae with a single species of a single genus. Bharti and Sharma (2011) found 35 species representing 7 species groups by surveying *Myrmica* fauna of southwestern slope of Himalaya. Out of them, 33 species (94.29 %) were endemic to this region. New species *Myrmica longisculpta* sp. was also described. Noor and Amirrudin (2014) compared diversity of ants at Kuala lompat, Krau wildlife reserve, Pahang, Malaysia on the march and may using handpicking and trapping method and found 25 species in March and 33 species in May belonging to 18 genera and five subfamilies. They suspect the unfavourable wet weather during sampling for less no. of species.

More recently, García-Martínez et al. (2015) analyzed the taxonomic, species and functional group diversity of ants in three neighbouring habitats with different degrees of anthropic disturbance in Veracruz, Mexico. A total of 34,957 ant workers belonging to 89 species, 34 genera, 19 tribes and 7 subfamilies were recorded in their survey; Primary forest had the highest species richness and most even distribution of species among the taxonomic levels, followed by secondary forest and active pasture. Thapa (2015) enlisted 52 species of 29 genera in his book Insect diversity in Nepal. He provided the data of 17 tribes belonging to 7 subfamilies. Mahalakshmi and Channaveerappa (2016) studied the diversity of ant species in the campus of maharani's science college for women by intensive all-out-search method and 20 species belonging to 12 genera and four subfamilies were reported. Sonune et al. (2016) investigate the distribution and diversity of ants (Hymenoptera: Formicidae) around Gautala Autramghat Sanctuary, Aurangabad Maharashtra, India by collecting ants randomly by all-out search method and a total of 17 species belonging to 13 genera and six subfamilies were recorded.

Adhikari (2016) studied ground-dwelling ants using pitfall traps, bait traps and manual collection in the forest, cultivated land and grassland of Lahachowk VDC in autumn 2015 and spring 2016 and reported 79 morphospecies belonging to 30 genera and 7 subfamilies. Subedi et al. (2019) listed 121 valid extant species of ants under 49 genera and eight subfamilies from different parts of Nepal. Neupane and Subedi (2018) studied ant diversity using pitfall traps, leaf litter sampling, bait and hand collection methods and collected 817 individuals representing 16 genera (*Pachycondyla* and *Echinopla* as new to Nepal) from 5 subfamilies. Formicinae was an abundant sub-family, followed by Myrmicinae; Species richness in winter was higher than in spring was seen in the study . Subedi and Budha (2019) listed all known species of *Myrmica* with their taxonomic notes (type species, type locality synonyms) and distribution (global and local) in Nepal.

3. MATERIALS AND METHODS

3.1. Study area

Champadevi hill (85˚ 14' E to 85˚ 17' E longitude and 27˚ 37' N to 27˚ 39' N latitude) is located at the southwestern part of Kathmandu valley. It is situated in the mid-hills of Sheshnarayan, Talkududechour, Matatirtha and Machhegaun villages. The study site comprises the altitudinal ranges from 1450 m – 2452 m asl.

Champadevi forest includes a secondary forest which was said to be completely exposed due to deforestation 40 years ago. Champadevi hill forest was handed over by the government to the local user group in 1990 and after that, it has been legalized as a community forest (Khatiwada 2010). The forest area is typically subtropical with rainy summer and dry winter. The temperature in summer ranges from 20^{o}C to 30^{o}C whereas winter temperature from 0^{o}C to 18 ^{o}C (Gautam 2012).

The dominant floral species of the area are *Pinus roxburghii*, *Myrica esculentat*, *Schima wallichii*, *Castanopsis* sp., *Rhododendron* spp., *Lyonia ovalifolia* and *Quercus* sp. (Khatiwada, 2010). Similarly, some NTFPs called *Swertia* spp., *Begonia* spp., *Myria* spp., *Berberis* sp., *Rubia manjith*, *Astilbe rivularis*, *Zanthoxylum armatus*, *Dioscorea* spp., many orchids and lichens as well as herbs like *Centella asiatica, Cynodon dactylon, Trifolium repense, Oxalis* sp., *Imparatus cylindrica* were also found (Subedi 1981).

The Champadevi hill on the southern side is mostly dominated by pine trees whereas the northern side is predominant by evergreen deciduous mixed forest. The study sites are famous for the presence of globally iconic wildlife fauna such as common leopard, spotted deer, fox, jackal, pheasant, many birds and butterflies.

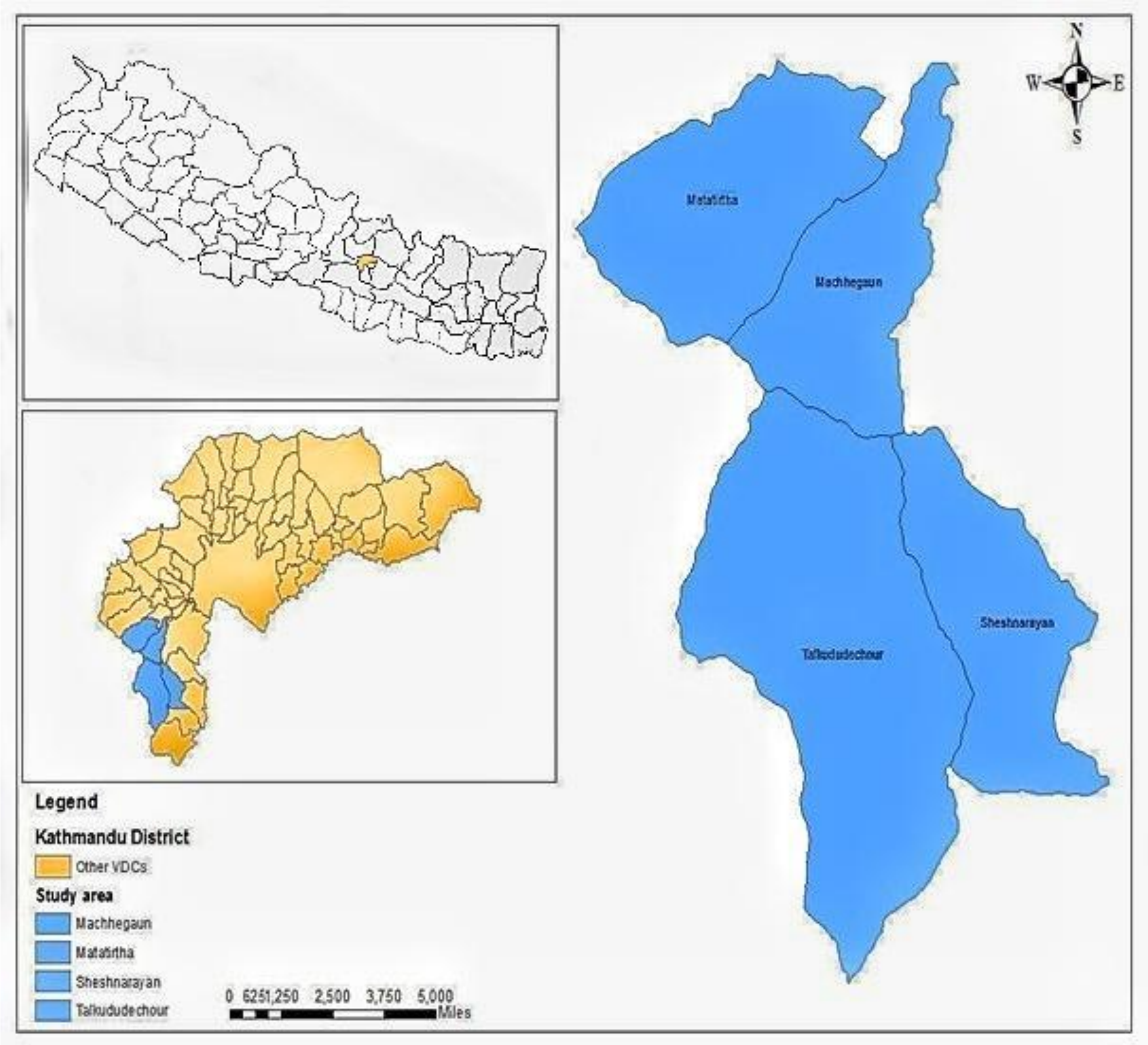


Figure 1: Map of the study area, Champadevi hill, Central Nepal.

3.2. Materials

a. GPS

b. Measuring tape

c. Vials

d. Feather-weight forceps

e. Stereo microscope

f. Camera

g. Chemicals (Ethanol and Glycol)

h. Brush

i. Pitfall traps

j. Digger (spade)

k. Cotton

3.3. Sampling methods

For sampling pitfall trapping and handpicking methods were used in an elevation ranging from 1450 m to 2452 m asl in Champadevi hill from Early May to Mid-November 2017.

The south and north sides of the Champadevi hill were taken as the study sites. Each side of the hill was divided horizontally into ten different plots. These plots were made according to the increasing elevation of 100 m each. In each plot, line transect of 150 m was made and 15 Pitfall traps (7 cm diameter, 9.5 cm high plastic recipients, one-third filled with ethylene glycol) were buried and exposed for 48 hours for collection of samples once in a month. Similarly, for the hand picking process, an all-out-search method was applied in potential microhabitats such as leaf litter, the base of the tree, tree trunk, foliage, fallen logs, stones and so on was searched at a different time thoroughly in semi-natural habitats and the sample specimen was collected using a featherweight forceps. The collected sample specimens from Pitfall traps and all-out-search methods were taken for further identification. Physical plot characteristics like topography, inclination, aspect, elevation, disturbance and canopy cover were recorded as well as GPS coordinates, temperature, humidity, time, date, number of individuals in each pitfall and trail of ants was also noted.

3.4. Sample sorting

All the collected samples were brought to the laboratory of the Central Department of Zoology, T.U. Kirtipur, Kathmandu, Nepal and were sorted into vials using featherweight forceps and brush and preserved in 70% alcohol.

3.4. Identification

Ants were abundant at the site and were relatively easy to collect in a standardized way and identifiable by their elbowed antennae and a distinctive node-like structure that forms their slender waists (Holldobler and Wilson 1990, Agosti et al. 2000). The collected specimens were identified in the laboratory with the help of identification guide to the ant genera of the world (Bolton 1994), a field guide to ants (Plowes and Patrock 2000), key to species (Collingwood 1958) and type images available at AntWeb (2017).

3.5. Specimen deposition

Specimens collected at the research field were deposited in the museum of the Central Department of Zoology (Entomology), T.U. Kirtipur, Kathmandu, Nepal.

3.6. Data analysis

3.6.1. Species richness

Test was carried out to find the correlation between geographic distance and distance in species richness and species composition by using the Mantel test as implemented in the package Vegan in R with 999 permutations in R 3.3.2 (R Development Core Team 2019). First, the Bray Curtis distance between all pairs of points using data on ant species richness was calculated. Then, the Euclidean distance between all pairs of points using data on ant species composition and geographic distance was calculated. In the case of significant associations of geographic distance and geographic position of the localities sampled, they were used as a covariate in the subsequent analyses (Basnet et al. 2016).

To find the determinant relationship between ant species richness and environmental variables (elevation, seasons, aspect, disturbance and vegetation canopy), a generalized linear model (GLM) with Poisson distribution and log link function was used. In the test species richness was used as response variable and environmental factors as predictors. Poisson distribution is used because data were not over-dispersed. The analyses were carried out using the lme4 function in lmerTest package in R 3.3.2 (R Development Core Team 2018). To find variation in significant values from one another, Tukey's post-hoc test was used. The figures were drawn using STATISTICA (StatSoft Inc 2015).

3.6.2. Species composition

Multivariate tests for the composition of ant communities were carried using a unimodal technique known as Canonical Correspondence Analysis (CCA) as gradient length was 2.39 (Lepš and Šmilauer 2014) by using Canoco 5.12 (Ter Braak and Smilauer 2012). Rare species, as defined in Ter Braak and Smilauer (2012), were down weighted to further reduce the negative effect of the occurrences of rare species on the results. These tests followed the same logic as the univariate analyses. First, elevation was tested for their significance and if significantly it was used as a covariate in the following test. Then we tested the effect of seasons, aspect, disturbance and vegetation canopy by using a forward stepwise selection procedure. Significant predictors were tested using Monte Carlo permutation test (n=4999). Finally, only the significant environmental variables were plotted in the graph.

4. RESULTS

4.1. Species richness

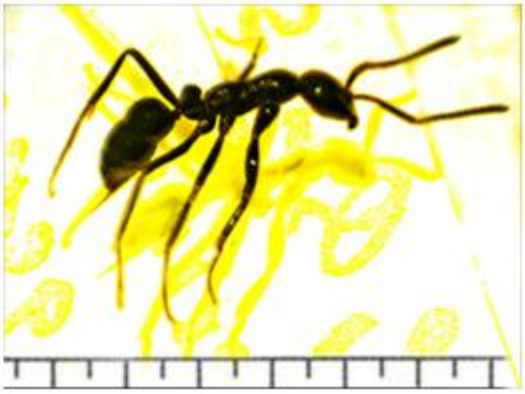
During the study, a total of 2558 individuals were captured from 1450 m to 2452 m elevation. Out of 2558 individuals, 33 genera of ants belonging to 6 subfamilies were identified. The subfamily Myrmicinae (13 genera) was largest followed by Formicinae (9 genera) and the subfamilies with least number of species were Ambylopone and Dorylinae (single genera) (Table 1). *Amblyopone* and *Ponera* were found as new genera to Nepal.

Table 1: Ant reported from Champadevi hill, Central Nepal.

S.N	Subfamily	Genus	Abbreviation	Abundance
1.	Amblyoponinae	*Amblyopone* Erichson, 1842	Amb	0.039%
2.	Dolichoderinae	*Dolichoderus* Lund, 1831	Dol	0.039%
		Technomyrmex Mayr, 1872	Tec	0.156%
3.	Dorylinae	*Aenictus* Shuckard, 1840	Aen	0.156%
4.	Formicinae	*Acropyga* Roger, 1862	Acro	0.039%
		Camponotus Mayr, 1861	Cam	10.399%
		Formica Linnaeus, 1758	For	0.117%
		Lepisiota Santschi, 1926	Lepi	11.415%
		Nylanderia Emery, 1906	Nyl	0.078%
		Paratrechina Motschoulsky, 1863	Par	2.306%
		Plagiolepis Mayr, 1861	Pla	1.368%
		Polyrhachis Smith, 1857	Pol	3.479%
		Prenolepis Mayr, 1861	Pre	4.066%
5.	Myrmicinae	*Aphaenogaster* Mayr, 1853	Aph	4.613%
		Cardiocondyla Emery, 1869	Car	0.117%
		Carebara (=*Pheidologeton*) Westwood, 1840	Phei	0.039%
		Crematogaster Lund, 1831	Cre	19.077%
		Lordomyrma Emery, 1897	Lor	0.586%
		Lophomyrmex Emery, 1982	Lop	0.391%

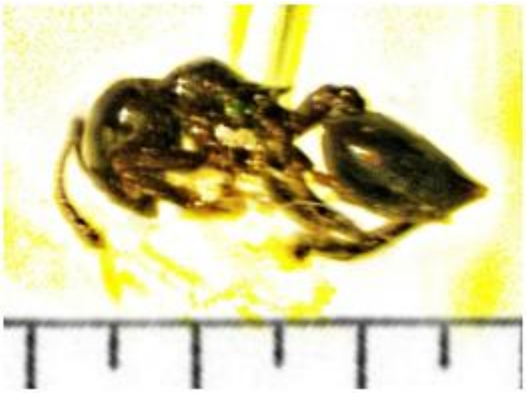
		Meranoplus Smith, 1853	Mer	0.156%
		Monomorium Mayr, 1855	Mon	0.078%
		Myrmica Latreille, 1804	Myr	1.368%
		Pheidole Westwood, 1839	Phe	19.977%
		Stenamma Westwood, 1839	Ste	1.994%
		Tetramorium Mayr, 1855	Tet	0.743%
		Trichomyrmex Mayr, 1865	Tri	0.313%
6.	Ponerinae	*Brachyponera* Emery, 1900	Bra	7.115%
		Harpegnathos Jerdon, 1851	Her	0.039%
		Leptogenys Roger, 1861	Lep	8.327%
		Odontomachus Latreille, 1804	OdoM	0.352%
		Odontoponera Mayr, 1862	Odo	0.117%
		Ponera Latreille, 1804	Pon	0.078%
		Pseudoneoponera Donisthorpe, 1943	Pse	0.860%
Total	6	33		

PHOTO PLATES



1. Genus *Leptogenys* (Ponerinae)

2. Genus *Camponotus* (Formicinae)



3. Genus *Crematogaster* (Myrmicinae)

4. Genus *Aenictus* (Dorylinae)

5. Genus *Dolichoderus* (Dolichoderinae)

6. Genus *Amblyopone* (Amblyoponinae)

Plate 1: Selected ant genera representing reported sub- families

Species richness decrease with increasing elevation of Champadevi hill, Central Nepal (Figure 2, Table 2). Species richness was highest in spring followed by summer and autumn season (Figure 3, Table 2). Ant species richness was higher in the north than the south aspect of the Champadevi hill (Figure 4, Table 2).

Table 2: Effect of different environmental variables (elevation, seasons, aspect, disturbance and vegetation canopy cover) on species richness of ant species in Champadevi hill, Central Nepal.

	Df	Deviance	Resid. Df	Resid. Dev	F Value	p-value	R^2
Elevation	1	12.300	118	50.955	31.410	<0.001	0.194
Seasons	2	4.040	116	46.915	5.160	0.007	0.064
Aspect	1	2.490	115	44.425	6.370	0.013	0.039
Disturbance	2	0.870	113	43.550	1.120	0.331	-
Canopy	1	0.050	112	43.500	0.130	0.723	-

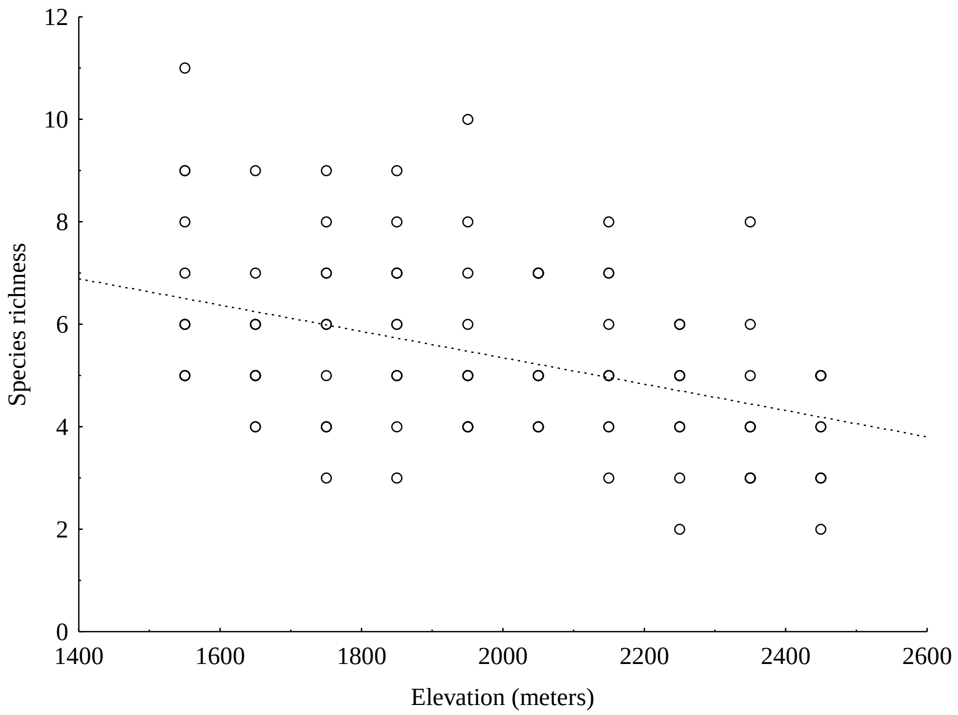


Figure 2: Relationship between species richness of ant species and elevation in the Champadevi hill, Central Nepal.

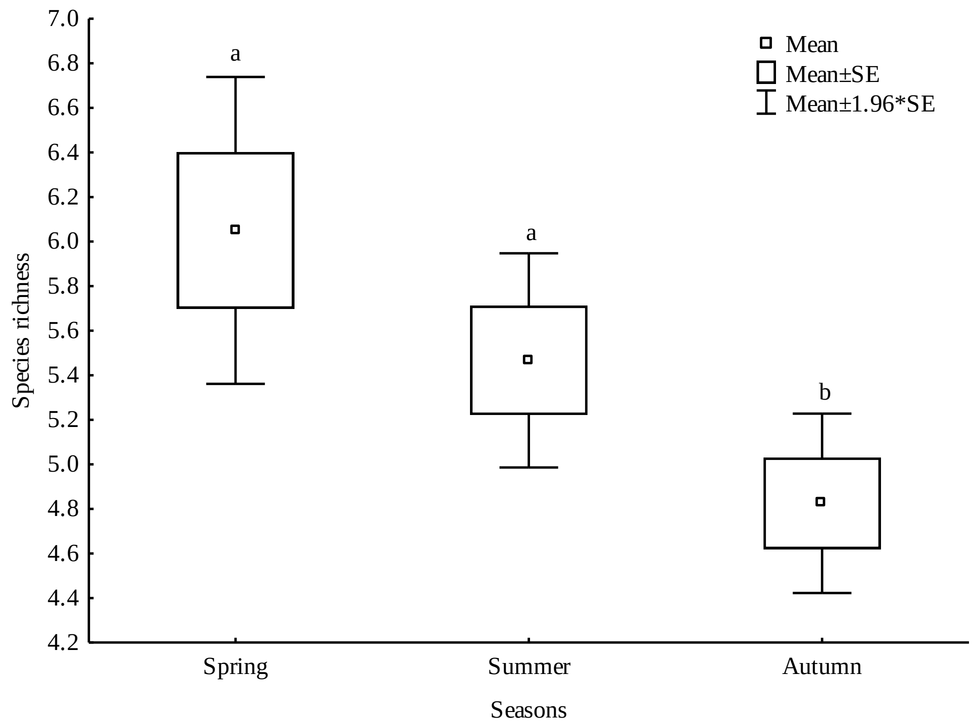


Figure 3: Relationship between species richness of ant species and seasons in the Champadevi hill, Central Nepal.

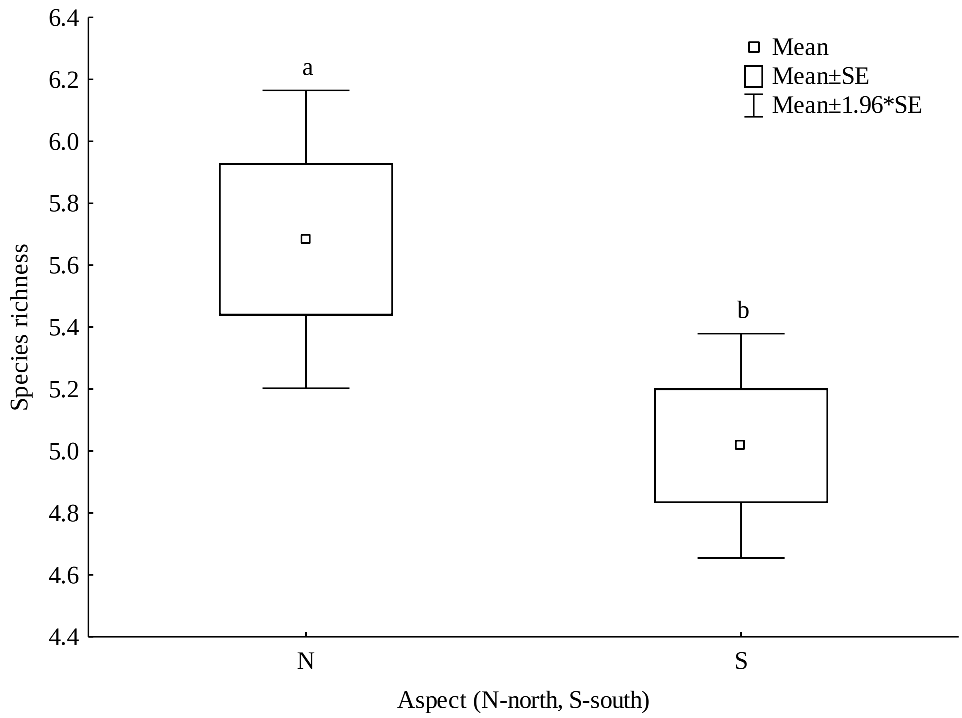


Figure 4: Relationship between species richness of ant species and aspects (north and south) in the Champadevi hill, Central Nepal.

4.2. Species composition

Species composition was significantly different in elevation, seasons and aspect of Champadevi hill (Figure 5, Table 3). *Pheidole* represents nearly 20% of ant species collected (Table 1) whereas Crematogaster represents about 19%, *Lepisiota* about 11% and *Camponotus* about 10% of total ants specimens collected. The figure of different ant species that occurred frequently shows that the species recorded in higher elevations were *Cardiocondyla, Tetramorium, Odontoponera, Formica, Amblyopone*. Species such as *Carebara, Meranoplus, Trichomyrmex, Herpegnathus, Nylanderia, Technomyrmex, Dolichoderus, Aenictus* prevailed at the lower elevations. Various ant genus like *Crematogaster, Pheidole, Lordomyrma, Lophomyrmex Monomorium, Aphenogaster, Myrmica, Stenemma, Ponera, Pseudoneoponera, Odontomachus, Leptogenys, Brachyponera, Prenolepis, Paratrechina, Plagiolepis, Acropyga, Camponotus, Polyrhachis, Lepisota* were independent of elevation.

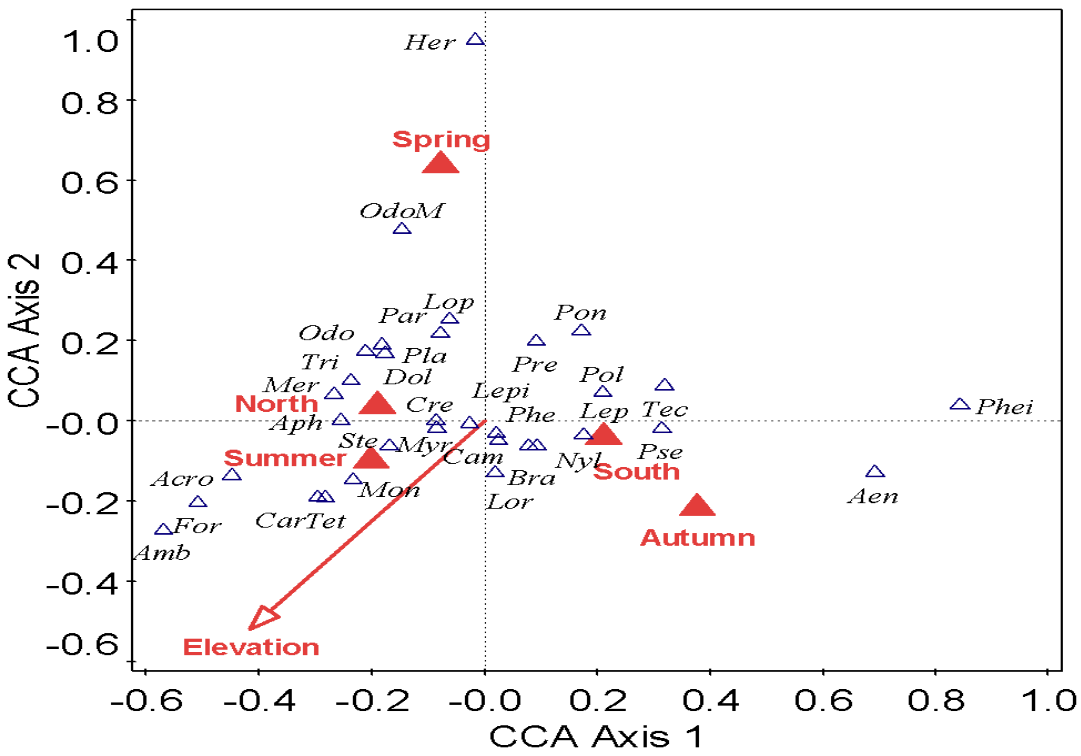


Figure 5: Associations between significant environmental variables (elevation, seasons and aspect) with ant communities in Champadevi hill, Central Nepal.

Table 3: Relationship between different environmental variables (elevation, seasons, aspect, disturbance and vegetation canopy cover) on species composition of ant species in Champadevi hill, Central Nepal.

	Sum of all canonical axis	p-value	R^2
Elevation	0.0450	0.004	0.021
Seasons	0.105	0.002	0.049
Aspect	0.045	0.002	0.021
Disturbance	-	0.054	-
Canopy	-	0.180	-

Ant genera like *Lophomyrmex, Trichomyrmex, Ponera, Harpegnathos, Odontoponera, Odontomachus, Polyrhachis, Prenolepis, Paratrechina, Plagiolepis* and *Dolichoderus* were observed in the spring season. Genera such as *Meranoplus, Cardiocondyla Tetramorium, Lordomyrma, Monomorium, Stenemma, Acropyga, Formica* and *Amblyopone* prevailed during the summer season. Different genera like *Carebara, Brachyponera, Nylanderia, Technomyrmex* and *Aenictus* prevailed in autumn. The composition of *Pheidole, Crematogaster, Aphenogaster, Myrmica, Pseudoneoponera, Leptogenys, Camponotus* and *Lepisiota* were independent of season.

Ant genera recorded in Northern aspect were *Monomorium, Aphenogaster, Cardiocondyla, Tetramorium, Lophomyrmex, Stenemma, Meranoplus, Trichomyrmex, Harpegnathos, Pseudoneoponera, Odontoponera, Odontomachus, Paratrechina, Plagiolepis, Acropyga, Formica, Dolichoderus* and *Amblyopone*. Genera such as *Carebara, Aenictus,Lordomyrma, Ponera, Leptogenys, Prenolepis, Nylanderia, Polyrhachis* and *Technomyrmex* prevailed at the Southern aspect. The composition of *Crematogaster, Pheidole, Camponotus, Myrmica, Brachyponera* and *Lepisiota*was independent of aspect.

5. DISCUSSION

5.1. Species richness

This is the first contribution to the taxonomy and ecological study of ants of Champadevi hill range. The study of the ground-dwelling ant fauna in Champadevi clearly demonstrates that much remains to be investigated about ant diversity in Nepal. Subedi et al. (2019) enlisted 49 genera and eight subfamilies from different parts of Nepal. The result of 33 ant genera recorded from ten 100 m transects from altitude 1450 m to 2450 m asl in the study area suggests a much higher ant diversity for the country than is currently known.

5.1.1. Species richness and elevation

The pattern of variation in species richness along an elevation of Champadevi hill follows the pattern of decrease as a function of elevation. Elevation was a significant predictor of ground-dwelling ant species richness (Fig. 2). The result resembles the most widely accepted pattern was a decrease in species richness with increasing elevation (Brown 1988, Stevens 1992). Olson (1994) also documented a similar rate of decrease of ant species richness in Panama. In Hong Kong, Fellowes (1996) also observed most tropical taxa were confined to lower elevations.

Kumar and O‟‟ Donnell (2009) revealed that army ants which forage above ground may be restricted to forested areas due to a thermal tolerance threshold. Similarly, Brown (1973) suggested that the reduction in ant diversity at higher elevations is the result of lower levels of radiant heat caused due to clouds and high humidity preventing bright sunlight from raising the ground temperature to the optimal level for larval development and for worker foraging activities. In Champadevi hill, the elevation bands less than 1800 m with the leaf litter layer in open grassland may receive more radiant heat during fog-free periods and thus support greater ant diversity than higher elevation bands.

Climatic, biological, geographical and historical factors have been suggested as causes of variation in species richness along elevation (Rahbek 1995, Rosenzweig 1995, Lomolino 2001, Sabu et al. 2008, Machac et al. 2010). The number of species declines with increasing latitude, altitude and aridity (Fowler and Claver 1991, Farji-Brener and Ruggiero 1994, Samson et al. 1997). Temperature, Precipitation and Thermal energy (Rahbek

1995, Bailey et al. 2004, Sanders et al. 2007, Barry 2008, Malsch et al. 2008, Szewczyk and McCain 2016), Light level, Slope and Vegetation (Robinson et al. 2003) could have both direct and indirect effects on ant diversity along elevation. The physiological stress of extreme elevation could limit species distributions (Ricklefs and Latham 1993). This fact is supported by the decline in the number of species in higher elevations of Champadevi hill.

5.1.2. Species richness and seasons

Seasonal variation was seen in species richness of ants in Champadevi Hill, Kathmandu, Nepal (fig. 3). The species richness was maximum during spring season than in autumn season. This result corresponds with research by Basu (1997) in Western Ghats, India, El Keroumi et al. (2012) in Argan forest, Lahssinate, Morocco and Adhikari (2016) in Lahachowk, Kaski, Nepal. They also recorded higher abundance and richness in the spring season than autumn season. This is due to the thermophilic nature of ants (Dunn et al. 2009). They were found to be less active during the coldest and driest time of the year (Rico-Gray et al. 1998). Temperature and moisture availability decrease in late autumn as a result ants alter their activity from late autumn and gradually halt their activities and process to hibernation due to cold. As the weather warmed in spring, activity of ants increased at different rates at different habitats (Levings 1983) as well as forage more and harvest more (Sanders et al. 2007). Food intake activity of ants was found to be increasing rapidly during April, with its peak in May (Horstman 1972). Physiologically, Ants face problems in gaseous exchange and low respiratory quotients resulting in reduction of metabolic activities when temperature steadily decreases in autumn (Dreyer 1932). Species richness varied in different seasons temperature and moisture availability (Adhikari 2016), precipitation (Barry 2008, Dunn et al. 2009), and contemporary climate between habitats (Gaston 1996, Hawkins et al. 2003, Brown et al. 2004, Hurlbert 2004, Hawkins et al. 2007).

5.1.3. Species richness and aspect

The species richness of ants in the northern aspect is higher than the southern aspect observed in Champadevi Hill, Kathmandu (fig. 4). Elevation and slope were significant predictors of species richness of various genera of ants (Ryder Wilkie et al. 2010). Similar study was made by Xu Zheng et al. (2001). They evaluated ant communities and their species diversity with altitudinal zonation on the west slope of Gaoligongshan Mountain in China. They observed high species richness at the north and north-middle section, but less at the south section. Food resources may have played an important role in influencing numbers of ant species (Watanasit et al. 2000) as ants experience seasonal shifts in their food resources (Cook et al. 2016). The causes of variation in species richness along elevation may be climatic, biological, geographical and historical factors (Rahbek 1995, Rosenzweig 1995, Lomolino 2001, Sabu et al. 2008, Machac et al. 2010) which alters along slope and aspect.

5.1.4. Species richness and disturbance and canopy cover

Disturbance and canopy cover were not significant predictors of species richness of various genera of ants along the elevational gradient of Champadevi Hill. Similar result was documented from Georgia by Graham et al. (2004). They documented such results due to fewer trees, diminished ground cover, warmer soils in the summer, and more compacted soils with a shallower horizon which is similar to our study site. Opposing this result, Savitha et al. (2008) found significant correlation between species richness and disturbance and canopy cover. It is due to the availability of specialized microhabitats.

5.2. Species composition

There are 33 ants genera recorded from the study area. Among them, six species (*Crematogaster, Pheidole, Leptogenys, Brachyponera, Camponotus* and *Lepisiota)* were common to all seasons, elevation and aspect. *Pheidole* represents nearly 20% of ant species collected (Table 1) whereas Crematogaster represents about 19%, *Lepisiota* about 11% and *Camponotus* about 10% of total ants specimens collected. This result matches with the study recorded *Pheidole, Camponotus* and *Crematogaster* as most predominant ant genera globally (Wilson 1976, Basu 1997, Ryder Wilkie et al. 2010, Adhikari 2016). The dominance of *Pheidole* is due to high environmental tolerance with temperature and humidity, as well as faster walking speeds (Tscha and pie 2018). Breaking down the number of the genus by subfamily, the result is accordant with other researches, in which the Myrmicinae represent the largest number of the total species (Table 1) (Ward 2000, Bruhl et al. 1998, Bharti and Sharma 2009, Narendra et al. 2010) followed by Formicinae and Ponerinae.

5.2.1. Species composition and elevation

The figure of different ant species that occurred frequently shows that the species recorded only in higher elevations were *Cardiocondyla, Tetramorium, Odontoponera, Formica, Amblyopone*. Species such as *Carebara, Meranoplus, Trichomyrmex, Harpegnathos, Nylanderia, Technomyrmex, Dolichoderus, Aenictus* prevailed at the lower elevations. The composition of 20 genera namely *Crematogaster, Pheidole, Lordomyrma, Monomorium, Aphenogaster, Myrmica, Stenemma, Ponera, Pseudoneoponera, Odontomachus, Leptogenys, Brachyponera, Prenolepis, Paratrechina, Plagiolepis, Acropyga, Camponotus, Polyrhachis, Lepisiota, Lophomyrmex* were independent of elevation (figure 5).

During the collection at various elevations, it is found that, *Pheidole* was frequently occurring species everywhere and found nestled in soil, *Crematogaster* nested in deadwood on trees and in open canopy areas. *Camponotus*, being a highly visual species, made it capture in leaf litters. These ants are called carpenter ants because of their "Nesting behaviours" (Chavhan and Pawar. 2011). The Ponerinae subfamily was more specific about its niche and food habits (Ramachandra et al. 2012). They feed on a wide range of food. Food resources may have played an important role in influencing numbers of Ponerinae (Watanasit et al. 2000). *Leptogenys* prefer cavities in logs or large branches to construct their nests and mostly found in fallen dead wood and rotten logs. Many ground-dwelling ants were collected by both pitfall method and all-out-search method but there are many arboreal ants which were only collected by all-out-search method and therefore occur sporadically in the dataset.

5.2.2. Species composition and seasons

During the study of seasonal composition of ants in Champadevi Hill, Kathmandu Nepal, four subfamilies namely Myrmicinae, Ponerinae, Formicinae and Dolichoderinae were found in the spring season. The different ant genera that were observed in the spring season are *Lophomyrmex, Trichomyrmex, Ponera, Harpegnathos, Odontoponera, Odontomachus, Polyrhachis, Prenolepis, Paratrechina, Plagiolepis* and *Dolichoderus*. Genera such as *Meranoplus, Cardiocondyla Tetramorium, Lordomyrma, Monomorium, Stenemma, Acropyga, Formica* and *Amblyopone* prevailed during the summer season. Genus *Amblyopone* was the only representative of subfamily Amblyoponinae, and was present in the summer season. Different genera like *Carebara, Brachyponera,* *Nylanderia, Technomyrmex* and *Aenictus* prevailed in autumn. The composition of *Pheidole, Crematogaster, Aphenogaster, Myrmica, Pseudoneoponera, Leptogenys, Camponotus* and *Lepisiota* were independent of season. The study shows these genera were able to withstand extreme temperature fluctuation (figure 5).

The study of species composition in the Champadevi shows typically thermophilic nature of ants (Dunn et al. 2009). They were found to be less active during the coldest and driest time of the year (Rico-Gray et al. 1998). They alter and gradually halt their activities and process to hibernation due to cold as Temperature and moisture availability decreases in late autumn. The composition of ant communities may be influenced by variation in resource availability and habitat quality (Palmer 2003, Boulton et al. 2005, Dauber et al. 2005), interspecific competition (Andersen and Patel 1994, Gibb 2005) and temporal changes in activity (Herbers 1985, Bestelmeyer 2000, Albrecht and Gotelli 2001). The presence and relative abundance of ants in some systems is affected by both habitat patch size and edge effects (Braschler and Baur 2003, Bruhl et al. 2003, Dauber and Wolters 2004).

5.2.3. Species composition and aspect

The figure of different ant species that occurred frequently shows that the species recorded in Northern aspect were *Monomorium, Aphenogaster, Cardiocondyla, Tetramorium, Lophomyrmex, Stenemma, Meranoplus, Trichomyrmex, Harpegnathos, Pseudoneoponera, Odontoponera, Odontomachus, Paratrechina, Plagiolepis, Acropyga, Formica, Dolichoderus* and *Amblyopone*. Species such as *Carebara, Aenictus, Lordomyrma, Ponera, Leptogenys, Prenolepis, Nylanderia, Polyrhachis* and *Technomyrmex* prevailed at the Southern aspect. The composition of *Crematogaster, Pheidole, Camponotus, Myrmica, Brachyponera* and *Lepisiota was* independent of aspect (figure 5).This shows; Species richness was maximum at the northern aspect of the Champadevi hill range, Kathmandu, Nepal.

The rich diversity of the ants in the northern aspect documented during this study is because of adequate nesting sites, availability of food as well foraging as well as composition of the plant species, invertebrate and microbial biomass (Majer 1982, Andersen 1997a, Andersen and Sparling 1997). We cannot deny the fact of the presence of primary forest in the northern aspect due to which ant diversity increased. Belshaw and Bolton (1993) studied the effect of forest disturbance on leaf litter ant fauna and concluded high ant diversity in primary forest leaf litter.

5.2.4. Species Composition and disturbance and canopy cover

Disturbance and canopy cover have no significant effect in ant species composition of Champadevi hill. This result is consistent with those of others who have studied ant communities in disturbed forest ecosystems (Majer 1983, Majer and Beeston 1996, Andersen 1997b). Majer and Nichols (1998) also found that ant communities in damaged ecosystems have lower species diversity and greater numbers of Dolichoderinae. Queiroz and Ribas (2016) found a negative correlation between canopy cover and species richness and composition as low canopy cover allows greater sunlight incidence and an increase in temperature, favoring ants that are adapted to open vegetation habitats. Savitha et al. (2008) found that *Paratrechina* in both disturbed and undisturbed sites which is common to research but *Monomorium* and *Camponotus* in more disturbed sites which was different from the result as they were present in both disturbed and undisturbed sites of Champadevi hill.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1. Conclusion

The present study was carried out to explore the diversityand distribution of ants along elevation gradientsin Champadevi hill range, Kathmandu. Altogether, six subfamilies and 33 genera were recorded from the study site. The pattern of variation in species richness along an elevation follows the pattern of decrease as a function of elevation The species richness was maximum during spring season as a total of 12 genera representing four subfamilies were collected during this season whereas in autumn season, only five genera were reported as well as the species richness in the northern aspect in maximum than southern aspect observed during the study of ants in Champadevi Hill range, Kathmandu.

The present study shows that Champadevi is rich in ant diversity. The systematic study could lead to the recording of more species in the country.

6.2. Recommendations

- Future surveys should be directed toward testing the efficacy of the ant survey methods in various habitats.
- More study is needed to determine individuals recorded in fact there is a complex of morphologically similar genus.
- Improved mapping of ant assemblages is important for understanding and responding to trends in ant biodiversity.
- Other effective methods like Winkler extractor, Berlese extraction, leaf litter shifting and canopy collection (canopy baits, canopy pitfalls) could be used for more exploration of ants.

7. REFERENCES

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ANNEXES

Annexes I: Composition of Genus of ants Recorded at Champadevi hill, Central Nepal.

Slope		S	S	S	S	S	S	S	S	S	S	N	N	N	N	N	N	N	N	N	N	S
Month		May	May	May	May	May	May	May	May	May	May	May	May	May	May	May	May	May	May	May	May	June
Elevation		1550	1650	1750	1850	1950	2050	2150	2250	2350	2450	1550	1650	1750	1850	1950	2050	2150	2250	2350	2450	1550
Plot		1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10	1
Canopy cover		5%	50%	30%	45%	5%	7%	50%	5%	30%	3%	25%	65%	90%	90%	80%	85%	9%	93%	15%	20%	5%
Disturbance		H	H	H	M	M	M	M	L	L	H	H	M	L	L	L	L	L	M	H	H	H
Genus																						
Acropyga	Acro																					
Aenictus	Aen																					
Amblyopone	Amb																					
Aphaenogaster	Aph			1	1						1							1	1	1	1	
Brachyponera	Bra	1	1	1	1			1	1							1						
Camponotus	Cam				1	1						1	1		1	1		1	1			1
Cardiocondyla	Car																				1	
Carebara	Phei																					
Crematogaster	Cre	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1
Dolichoderus	Dol																					
Formica	For																					
Harpegnathos	Her											1										
Lepisiota	Lepi		1	1		1	1				1	1	1	1	1	1		1	1			1

Leptogenys	Lep	1	1				1					1	1									1
Lophomyrmex	Lop					1		1				1										
Lordomyrma	Lor																					
Meranoplus	Mer																					
Monomorium	Mon																					
Myrmica	Myr															1	1	1				
Nylanderia	Nyl																					
Odontomachus	Odo M					1					1			1	1							
Odontoponera	Odo															1						
Paratrechina	Par	1	1						1			1	1							1	1	
Pheidole	Phe			1	1	1	1	1	1	1	1	1				1	1		1	1	1	1
Plagiolepis	Pla													1	1	1	1					
Polyrhachis	Pol	1		1				1	1			1	1				1	1				
Ponera	Pon																			1		
Prenolepis	Pre	1	1		1	1	1	1		1	1		1			1	1					
Pseudoneoponera	Pse																					
Stenamma	Ste															1	1	1	1			
Technomyrmex	Tec																					
Tetramorium	Tet																			1		
Trichomyrmex	Tri																					

Slope		S	S	S	S	S	S	S	S	S	S	N	N	N	N	N	N	N	N	N	N
Month		June	June	June	June	June	June	June	June	June	June	June	June	June	June	June	June	June	June	June	June
Elevation		1550	1650	1750	1850	1950	2050	2150	2250	2350	2450	1550	1650	1750	1850	1950	2050	2150	2250	2350	2450
Plot		1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
Canopy cover		5%	50%	30%	45%	5%	7%	50%	5%	30%	3%	25%	65%	90%	90%	80%	85%	9%	93%	15%	20%
Disturbance		H	H	H	M	M	M	M	L	L	H	H	M	L	L	L	L	L	M	H	H
Genus																					
Acropyga	Acro																				
Aenictus	Aen																				
Amblyopone	Amb																				
Aphaenogaster	Aph							1		1	1			1		1	1	1			
Brachyponera	Bra				1			1		1		1	1	1	1						
Camponotus	Cam	1		1		1	1	1		1		1	1	1	1	1			1		
Cardiocondyla	Car																				
Carebara	Phei																				
Crematogaster	Cre	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
Dolichoderus	Dol																				
Formica	For																	1			
Harpegnathos	Her																				
Lepisiota	Lepi	1	1								1	1	1	1	1	1	1	1	1	1	1
Leptogenys	Lep	1	1	1	1	1	1	1		1											
Lophomyrmex	Lop																				
Lordomyrma	Lor		1				1	1													
Meranoplus	Mer																				
Monomorium	Mon													1	1						
Myrmica	Myr																				

Nylanderia	Nyl																				
Odontomachus	OdoM																				
Odontoponera	Odo								1												
Paratrechina	Par																	1			
Pheidole	Phe	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1			1
Plagiolepis	Pla									1	1			1	1						
Polyrhachis	Pol					1		1		1											
Ponera	Pon																				
Prenolepis	Pre																				
Pseudoneoponera	Pse																				
Stenamma	Ste																	1	1		
Technomyrmex	Tec																				
Tetramorium	Tet																			1	1
Trichomyrmex	Tri																				

Slope		S	S	S	S	S	S	S	S	S	S	N	N	N	N	N	N	N	N	N	N
Month		July	July	July	July	July	July	July	July	July	July	July	July	July	July	July	July	July	July	July	July
Elevation		1550	1650	1750	1850	1950	2050	2150	2250	2350	2450	1550	1650	1750	1850	1950	2050	2150	2250	2350	2450
Plot		1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
Canopy cover		5%	50%	30%	45%	5%	7%	50%	5%	30%	3%	25%	65%	90%	90%	80%	85%	9%	93%	15%	20%
Disturbance		H	H	H	M	M	M	M	L	L	H	H	M	L	L	L	L	L	M	H	H
Genus																					
Acropyga	Acro																				
Aenictus	Aen																				
Amblyopone	Amb																		1		
Aphaenogaster	Aph			1				1		1	1			1	1	1		1	1	1	
Brachyponera	Bra											1			1	1	1	1	1	1	1
Camponotus	Cam					1	1		1		1	1	1	1	1						
Cardiocondyla	Car									1											
Carebara	Phei																				
Crematogaster	Cre	1	1		1	1	1	1		1	1	1	1	1	1	1	1	1	1		1
Dolichoderus	Dol											1	1								
Formica	For																				
Harpegnathos	Her																				
Lepisiota	Lepi	1	1	1	1	1	1	1	1	1			1		1	1	1	1		1	1
Leptogenys	Lep			1				1	1			1									
Lophomyrmex	Lop							1						1							
Lordomyrma	Lor																				
Meranoplus	Mer																				

Monomorium	Mon																				
Myrmica	Myr	1		1	1											1					1
Nylanderia	Nyl				1																
Odontomachus	OdoM																				
Odontoponera	Odo																				
Paratrechina	Par	1			1											1	1				
Pheidole	Phe		1		1	1	1		1		1	1	1	1	1	1	1		1		1
Plagiolepis	Pla			1								1	1		1						
Polyrhachis	Pol																				
Ponera	Pon																				
Prenolepis	Pre	1	1	1								1		1	1	1	1				
Pseudoneoponera	Pse											1	1								
Stenamma	Ste											1					1	1		1	
Technomyrmex	Tec												1								
Tetramorium	Tet																			1	
Trichomyrmex	Tri											1	1		1						

Slope		S	S	S	S	S	S	S	S	S	S	N	N	N	N	N	N	N	N	N	N
Month		Aug	Aug	Aug	Aug	Aug	Aug	Aug	Aug	Aug	Aug	Aug	Aug	Aug	Aug	Aug	Aug	Aug	Aug	Aug	Aug
Elevation		1550	1650	1750	1850	1950	2050	2150	2250	2350	2450	1550	1650	1750	1850	1950	2050	2150	2250	2350	2450
Plot		1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
Canopy cover		5%	50%	30%	45%	5%	7%	50%	5%	30%	3%	25%	65%	90%	90%	80%	85%	9%	93%	15%	20%
Disturbance		H	H	H	M	M	M	M	L	L	H	H	M	L	L	L	L	L	M	H	H
Genus																					
Acropyga	Acro																1				
Aenictus	Aen																				
Amblyopone	Amb																				
Aphaenogaster	Aph											1	1		1			1	1		
Brachyponera	Bra		1	1	1	1	1		1	1				1			1			1	1
Camponotus	Cam	1	1	1	1	1	1					1	1	1	1	1		1	1		
Cardiocondyla	Car																				
Carebara	Phei																				
Crematogaster	Cre	1		1	1	1	1	1	1		1	1	1	1	1	1	1	1	1		
Dolichoderus	Dol																				
Formica	For																				
Harpegnathos	Her																				
Lepisiota	Lepi	1	1				1		1	1	1	1	1	1	1		1	1	1		
Leptogenys	Lep	1	1	1	1	1								1							
Lophomyrmex	Lop								1												
Lordomyrma	Lor																				
Meranoplus	Mer													1							
Monomorium	Mon																				
Myrmica	Myr	1						1	1	1											1

Nylanderia	Nyl																				
Odontomachus	OdoM															1					
Odontoponera	Odo																				
Paratrechina	Par			1								1	1		1						
Pheidole	Phe	1	1	1	1	1	1	1				1	1	1	1		1		1		1
Plagiolepis	Pla		1																		
Polyrhachis	Pol			1													1				
Ponera	Pon																				
Prenolepis	Pre											1			1	1					
Pseudoneoponera	Pse	1					1					1									
Stenamma	Ste					1	1		1			1		1			1	1		1	
Technomyrmex	Tec																				
Tetramorium	Tet							1												1	
Trichomyrmex	Tri													1							

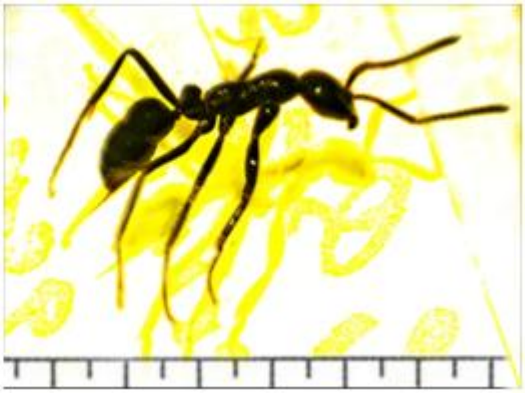
Slope		S	S	S	S	S	S	S	S	S	S	N	N	N	N	N	N	N	N	N	N
Month		Se pt	Sept	Sept	Sept	Sept	Sept	Sept	Sept	Sept	Sept	Sept	Sept	Sept	Sept	Sept	Sept	Sept	Sept	Sept	Sept
Elevation		15 50	165 0	175 0	185 0	195 0	205 0	215 0	225 0	235 0	245 0	155 0	165 0	175 0	185 0	195 0	205 0	215 0	225 0	235 0	245 0
Plot		1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
Canopy cover		5%	50%	30%	45%	5%	7%	50%	5%	30%	3%	25%	65%	90%	90%	80%	85%	9%	93%	15%	20%
Disturbance		H	H	H	M	M	M	M	L	L	H	H	M	L	L	L	L	L	M	H	H
Genus																					
Acropyga	Acro																				
Aenictus	Aen			1	1																
Amblyopone	Amb																				
Aphaenogaster	Aph																				
Brachyponera	Bra	1	1	1	1	1	1	1	1	1	1	1	1		1	1		1	1		
Camponotus	Cam				1	1	1		1	1	1	1	1		1			1	1	1	
Cardiocondyla	Car																				
Carebara	Phei	1																			
rematogaster	Cre	1	1	1	1		1	1	1	1	1	1	1			1	1	1	1	1	1
Dolichoderus	Dol																				
Formica	For																				
Harpegnathos	Her																				
Lepisiota	Lepi		1		1		1		1	1	1					1	1				
Leptogenys	Lep		1	1	1			1						1	1	1	1	1	1	1	1
Lophomyrmex	Lop																				
Lordomyrma	Lor																				
Meranoplus	Mer																				
Monomorium	Mon																				1
Myrmica	Myr	1																			

Nylanderia	Nyl																				
Odontomachus	Odo M																				
Odontoponera	Odo																				
Paratrechina	Par																1				
Pheidole	Phe	1	1			1	1	1				1	1		1	1	1	1	1	1	
Plagiolepis	Pla																				
Polyrhachis	Pol	1		1	1	1	1		1			1									
Ponera	Pon	1																			
Prenolepis	Pre				1			1				1		1							
Pseudoneoponera	Pse																				
Stenamma	Ste						1		1						1						
Technomyrmex	Tec	1																			
Tetramorium	Tet													1							
Trichomyrmex	Tri																				

Slope		S	S	S	S	S	S	S	S	S	S	N	N	N	N	N	N	N	N	N	N
Month		Nov	Nov	Nov	Nov	Nov	Nov	Nov	Nov	Nov	Nov	Nov	Nov	Nov	Nov	Nov	Nov	Nov	Nov	Nov	Nov
Elevation		1550	1650	1750	1850	1950	2050	2150	2250	2350	2450	1550	1650	1750	1850	1950	2050	2150	2250	2350	2450
Plot		1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
Canopy cover		5%	50%	30%	45%	5%	7%	50%	5%	30%	3%	25%	65%	90%	90%	80%	85%	9%	93%	15%	20%
Disturbance		H	H	H	M	M	M	M	L	L	H	H	M	L	L	L	L	L	M	H	H
Genus																					
Acropyga	Acro																				
Aenictus	Aen																				
Amblyopone	Amb																				
Aphaenogaster	Aph											1	1								
Brachyponera	Bra	1	1	1	1					1	1			1	1						
Camponotus	Cam	1	1					1	1	1	1			1	1			1	1	1	1
Cardiocondyla	Car																				1
Carebara	Phei																				
Crematogaster	Cre					1	1				1	1	1	1	1	1	1			1	1
Dolichoderus	Dol																				
Formica	For																				
Harpegnathos	Her																				
Lepisiota	Lepi											1	1		1		1	1	1		
Leptogenys	Lep			1		1	1						1	1	1		1	1	1		
Lophomyrmex	Lop																				
Lordomyrma	Lor																				
Meranoplus	Mer																				
Monomorium	Mon																				
Myrmica	Myr									1											
Nylanderia	Nyl																				

Odontomachus	OdoM																				
Odontoponera	Odo																				
Paratrechina	Par														1		1				
Pheidole	Phe	1	1	1	1	1	1	1	1	1	1	1	1	1		1		1	1	1	.
Plagiolepis	Pla																				
Polyrhachis	Pol					1	1	1							1	1					1
Ponera	Pon																				
Prenolepis	Pre	1	1									1		1		1			1		
Pseudoneoponera	Pse	1	1	1	1				1												
Stenamma	Ste										1			1		1	1				
Technomyrmex	Tec																				
Tetramorium	Tet											1									1
Trichomyrmex	Tri																				

Annexes II: Photos of Ants genera recorded at Champadevi hill, Central Nepal.



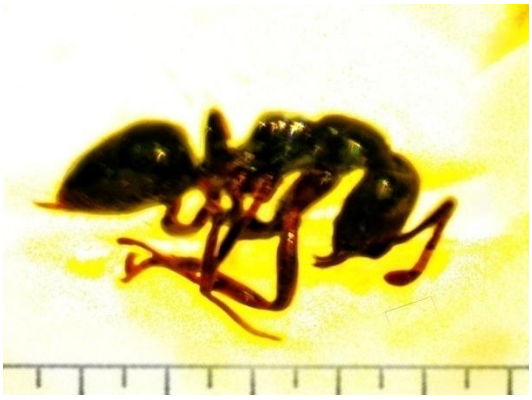
Genus *Leptogenys* (Ponerinae)

Genus *Harpegnathos* (Ponerinae)

Genus *Odontoponera* (Ponerinae)

Genus *Pseudoneoponera* (Ponerinae)

Genus *Ponera* (Ponerinae)



Genus *Brachyponera* (Ponerinae)

Genus *Odontomachus* (Ponerinae)

Genus *Camponotus* (Formicinae)

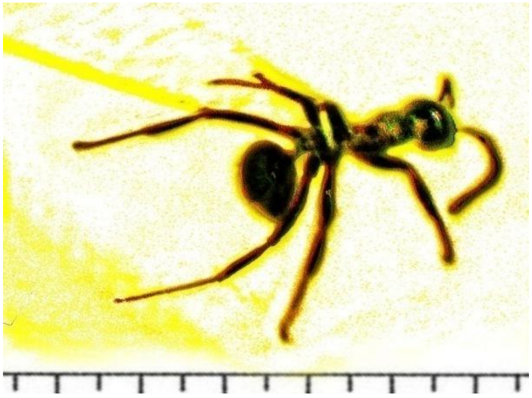
Genus *Prenolepis* (Formicinae)

Genus *Formica* (Formicinae)

Genus *Paratrechina* (Formicinae)

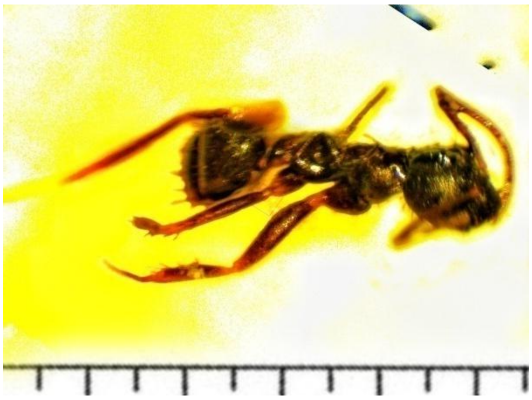
Genus *Nylanderia* (Formicinae)

Genus *Acropyga* (Formicinae)

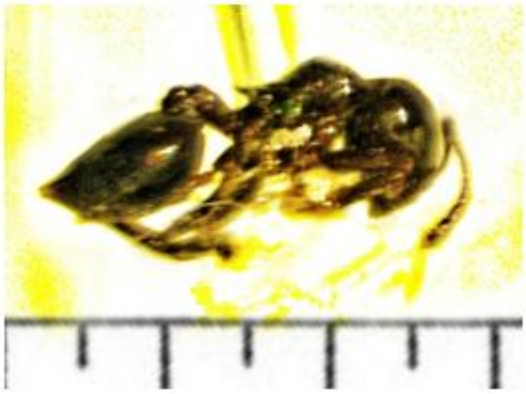


Genus *Lepisiota* (Formicinae)

Genus *Polyrhachis* (Formicinae)



Genus *Plagiolepis* (Formicinae)

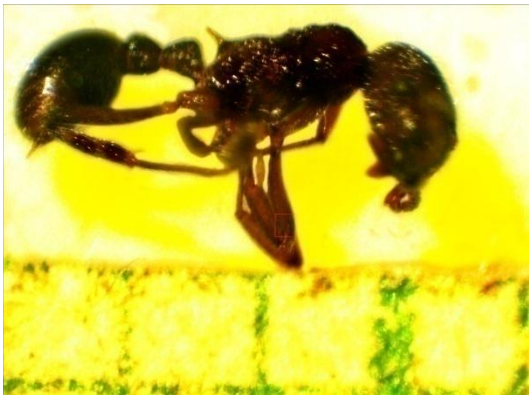


Genus *Crematogaster* (Myrmicinae)

Genus *Trichomyrmex* (Myrmicinae)

Genus *Tetramorium* (Myrmicinae)

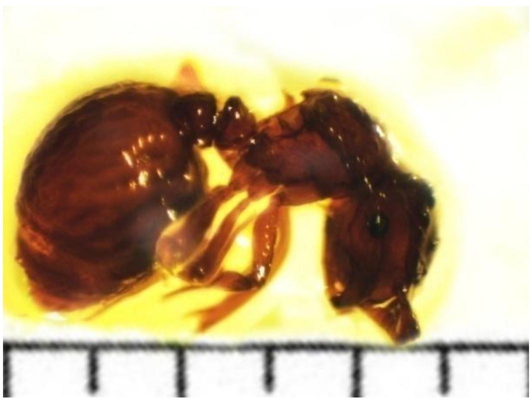
Genus *Stenemma* (Myrmicinae)



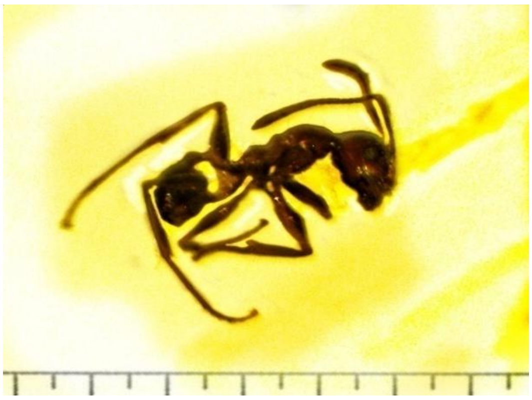
Genus *Myrmica* (Myrmicinae)

Genus *Carebara* (Myrmicinae)

Genus *Pheidole* (Myrmicinae)

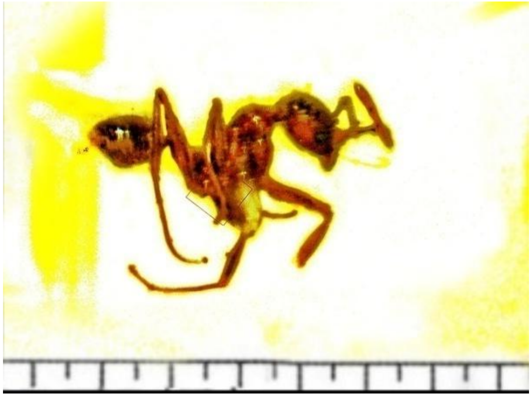


Genus *Meranoplus* (Myrmicinae)



Genus *Lordomyrma* (Myrmicinae)

Genus *Amblyopone* (Amblyoponinae)



Genus *Lophomyrmex* (Myrmicinae)

Genus *Dolichoderus* (Dolichoderinae)

Genus *Aphaenogaster* (Myrmicinae)

Genus *Technomyrmex* (Dolichoderinae)

Genus *Monomorium* (Myrmicinae)

Genus *Aenictus* (Dorylinae)