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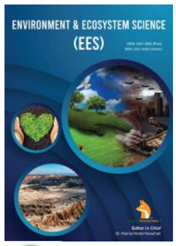

RESEARCH ARTICLE

EFFECTS OF VEGETATION TYPES AND HABITAT DISTURBANCE ON SPECIES RICHNESS AND COMPOSITION OF ANT (HYMENOPTERA, FORMICIDAE) ASSEMBLAGES IN LAWACHARA NATIONAL PARK, BANGLADESH

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ABSTRACT

Ants, because of their diversity, abundance, and functional roles in the ecosystem, play a crucial role in understanding the effects of habitat loss and fragmentation on community ecology. Thus, the influence of the structural complexity of the environment on the richness and diversity of ants makes them a potential ecological indicator. Although there exist numerous studies on ant species richness in different countries, such studies are rare in Bangladesh. To fill-up this information gap, the present study was conducted in Lawachara National Park, Bangladesh, a conservation site with abundant natural resources. The purpose of this study was to describe the richness and composition of local ant assemblage in the forest ecosystem and understand their structural diversity on different types of plants and disturbance patterns. Time unit sampling and pitfall traps were used to perform sampling from two different areas, viz, primary forest and secondary forest. A total of 843 ant individuals was identified from 48 species of 17 genera distributed among 6 subfamilies. Myrmicinae was the most abundant ant subfamily in the study area. Most of the species found were from the genus Pheidole. The rarefaction curves showed higher species richness in areas with reforestation. The richness pattern of species found in two areas denoted that vegetation and soil conditions may affect the overall diversity and composition of ants. This can be considered as the first extensive list of ant assemblages from Lawachara National Park. These findings will provide comprehensive data for using ants as bioindicators in natural protected areas.

KEYWORDS

Ant diversity, Primary and secondary forest, Time Unit Sampling, Rarefaction Curve

1. INTRODUCTION

Species richness is considered as one of the major factors controlling ecosystem process and function (Tilman et al., 2014). Consequently, it is important to assess the effect of various threats to biodiversity on the composition of species (Barlow et al., 2016; Martínez-Ramos et al., 2016). One such threat is the anthropogenic disturbance which affects the interaction within communities and subsequent ecological function (Barlow et al., 2016; Ewers et al., 2015; Gray et al., 2018). In-depth knowledge regarding the change in community composition is required to understand the effect of such disturbance (Gibson et al., 2011).

Ants are eusocial organisms that play an important role in the ecosystem as biological agents of insect pests, gardeners, mutualists, predators, soil engineers, and scavengers (Pal and McSpadden Gardener, 2006). In terms of biomass and species richness, ants are one of the most important groups of any terrestrial ecosystem. They control the structure and function of these ecosystems by affecting soil fertility and structure, nutrient cycling, indicating the ecological change, and influencing other fauna and flora (Dostal et al., 2005; Morales-Linares et al., 2017; Andersen and Majer, 2004; Vieira and Hofer, 1998; Vasconcelos, 1991). Due to this intimate association with fauna and flora, they can potentially serve as bioindicators as they provide an estimate of the extent of environmental preservation (Lutinski et al., 2017a). The biodiversity of ants is affected by anthropogenic impacts, land disturbance, and different biotic and abiotic factors. These factors influence the species richness and distributions of ants (Morales-Linares et al., 2021; Nayana et al., 2016).

Many studies have been conducted recently on the diversity of ants in many countries such as Australia (Lawes et al., 2017), Brazil (Aguiar et al., 2021; Franco et al., 2021; J A Lutinski et al., 2017b; Marques et al., 2017; Santos et al., 2021; Silva et al., 2017; Siqueira and Silva, 2021), Croatia (Ješovnik and Bujan, 2021), Ecuador (Tiede et al., 2017), France (De Almeida et al., 2020), India (Begum et al., 2021), Indonesia (Hood et al., 2020), Italy (Guariento and Fiedler, 2021), Madagascar (Camacho et al., 2021), and Mexico (Pérez-Toledo et al., 2021). These studies focus on evaluating ant diversity in areas with different land use pattern (Begum et al., 2021; De Almeida et al., 2020; Franco et al., 2021; Hood et al., 2020; J A Lutinski et al., 2017b; Rocha-Ortega et al., 2018; Santos et al., 2021), examine their functional group responses (Aguiar et al., 2021; Lawes et al., 2017; Tiede et al., 2017), assess the effect of vegetation type on ant richness (Camacho et al., 2021; Siqueira and Silva, 2021), and investigate

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the effect of different environmental conditions on ant composition (Guariento and Fiedler, 2021; Ješovnik and Bujan, 2021). This information is used to facilitate the identification of ants that serves as a baseline for species and ecosystem conservation (Guariento and Fiedler, 2021; Tiede et al., 2017), assess the uniqueness, variability, and risk associated with the ecosystem (Aguiar et al., 2021; Franco et al., 2021; Gaytán et al., 2021), highlight the key threats towards the biodiversity (Santos et al., 2021), understand the effects of ecosystem restoration methods (De Almeida et al., 2020; Lawes et al., 2017; J A Lutinski et al., 2017b; Marques et al., 2017; Siqueira and Silva, 2021), quantify the biodiversity loss (Begum et al., 2021; Camacho et al., 2021), design conservation strategy (Arnan et al., 2017; Hood et al., 2020; Ješovnik and Bujan, 2021; Silva et al., 2017), and improve the ability to control the ant community in order to increase the efficiency and resilience of managed ecosystem (Fellowes et al., 2020). Recently, few studies have been conducted in Bangladesh to assess and conserve plant diversity and animal biodiversity (Chowdhury et al., 2019; Rahman and Jahan, 2020). Our aim is to understand the diversity and abundance of ants and correlate their presence with the habitat condition of our study area.

2. Materials and Methods

2.1 Study Area

About 60 km south of Sylhet, Lawachara National Park is located in the Kamalganj Upazila of Moulvi Bazar district. Along with the forest, the park covers a total area of 1250 ha (Uddin and Hassan, 2010). The forest is a part of the West Bhanugach reserve forest, which was declared a reserve in the early 19th century. The forest is covered with deciduous canopies, and evergreen understories consisting of a few exotic herbs, shrubs, creepers, and climbers (Larsen, 2004). The topography of the forest can be classified as slopes and hillocks rising up to 10 to 50m surrounding numerous streams flowing through the forest (Riadh, 2007). The hills are mostly composed of upper tertiary rocks consisting of sandstone, mudstone, and siltstone among other upper tertiary rocks (Stevens, 1986). Soils consist of sandy and clayey loam (Ahmad, 1970). These reasons make Lawachara National Park an ideal place for the study of ant species richness and composition.

2.2 Habitat Characterization

A moist tropical climate is prevalent in this area with high precipitation from April to September and a relatively dry period from November to March (Uddin and Hassan, 2010). A total of 374 plant species consisting of 65 climber species, 90 tree species, 71 shrubs species, and 148 herb species have been identified in the area (Uddin and Hassan, 2010). Plants include *Artocarpus chaplasha*, *Dillenia pentagyna*, *Dipterocarpus turbinatus*, *Elaeocarpus floribundus*, etc. Among vegetation, *Aphania danura*, *Erioglossum edulis*, *Grewia microcos*, *Micromelum minutum,* etc. are commonly found (Uddin and Hassan, 2010).

Although Lawachara National Park is a reserve forest, it has various interesting ecological properties. A portion of the forest is densely populated with old and tall (average height 30m) trees which reduces the amount of light that reaches the ground resulting in high moisture content of the soil. In this study, we consider this area as Primary Forest. In the other part of the forest, newly planted shrubs can be seen along with the old trees. This is a part of the restoration project inside the park area (Rahman et al., 2017). This area is considered Secondary Forest. Additionally, to understand the impact of human intervention, each forest was divided into two subareas: Human Intervention Forest having human disturbance, train line and common passageway for the villagers, and Reserved Forest with limited human intervention.

2.3 Sample Collection

The collection of ants was conducted during October 2016 and November 2016 in Lawachara National Park (24^{o} 19'11" N 91^{o} 47'1" E). Two methods were followed to perform sampling, namely Time-Unit Sampling (TUS) and pitfall traps (Ogata, 2001). Following the TUS method, the entire collection process was split into four time-units, each consisting of 15 minutes. Each of the 4 areas was sampled 4 times following the same procedure. The process was conducted by two persons for 30+ minutes (+ denotes the time difference between two time-units). During the collection process, the ants were searched on the ground, on lower vegetation, and under shelters. Found samples were collected using forceps and stored in vials containing 70% ethanol. Samples from each time unit were stored in their own vials due to the independence of the time units. On the other hand, for setting up pitfall traps, a 50m transect was established in each subarea. 5 small containers were placed 10m apart along the transect. Plastic cups, with a diameter of 8cm and a depth of 15 cm, were used to act as containers. The cups were half-filled with ethylene glycol. The top level of the cup was surrounded by the surface. Ants fell into the cups during roaming around. After 5 days, the trapped samples were collected and stored in vials for further processing.

2.4 Sample Processing and Identification

To remove dirt or any other materials, the collected specimens were cleaned using a water-dipped brush and washed in alcohol. Then, they were sorted into similar groups and put into separate vials with proper labeling. After drying, the samples were inspected using an electronic microscope in order to identify them according to their taxonomic keys (Bolton, 1994). Finally, the identified samples were labeled and stored in the laboratory of the Department of Entomology of Bangabandhu Sheikh Mujibur Rahman Agricultural University, Bangladesh for future references.

2.5 Statistical Analysis

2.5.1 Shannon-Wiener Diversity Index

To determine the species diversity of the primary and secondary forests, the Shannon-Wiener Diversity Index (H') was calculated (Krebs, 1999). Typical values of this index range from 1.5 to 3.5 in most ecological studies. An increase in the index value denotes the increase in both the richness and evenness of a community.

$$H' = \sum_{i=1}^{s} p_i \ln(p_i)$$

Here, s is the number of species, and p_i is the fraction of the total samples that belong to the ith species.

2.5.2 The Evenness Index

To calculate the abundance of ant species in each forest, the Evenness Index (J') was used (Krebs, 1999). Typical values of this index range from 0 to 1. A value less than 0.5 indicates a depressed community. If the value is greater than 0.5 but less than 0.75, it indicates an unstable community. If the value is higher than 0.75, it indicates a stable community (Ulfah et al., 2019).

$$J' = \frac{H'}{H'_{max}}$$

Here, $H'$is the observed index of species diversity, and H'_{max} is the highest possible index of species diversity.

2.5.3 Effective Number of Species

To find the true diversity of the two forests, the Effective Number of Species (ENS) was used (Jost, 2006). It utilizes the index of species diversity to estimate the actual diversity that can be used for comparison of the two forests in question.

$$ENS = e^{H'}$$

Here,

H'= The observed index of species diversity

2.5.4 Rarefaction Curve

Rarefaction is a technique of calculating species richness given the number of samples by constructing the rarefaction curve (Gotelli and Colwell, 2001). The curve plots the number of species as a function of the number of samples. It grows rapidly at first, indicating the most common species found, and later slow down as only the rarest species remain to be sampled. Python library EcoPy was used to generate the rarefaction curves.

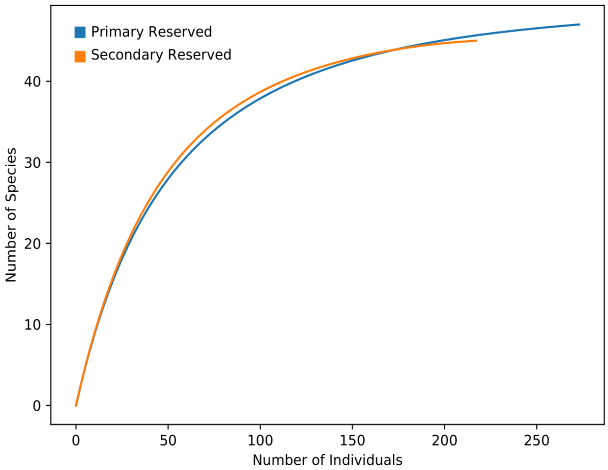
3. Results and Discussion

A total of 843 ant individuals from 6 subfamilies, 17 genera, and 48 species were sampled. Myrmicinae was the richest subfamily, with 25 species, followed by Ponerinae (9), Dorylinae (7), Dolichoderinae (3), Pseudomyrmecinae (3), and Formicinae (1). The richest genera were Pheidole (10 species) and Camponotus (6). Overall, the primary forest had 48 species, while the secondary forest had 47 species. Variations were noticed in the number of species found in different habitats, with human intervened subareas having a smaller number of unique species than that of the reserved one. In the subarea of the primary forest where human intervention is allowed, the number of species found was 42 and in the reserved subarea the species found were 47. Although the variety of species found in both forests are similar, the total number of individuals found in the primary forest was 455, whereas the number dropped to 388 for the secondary forest. The primary forest presents mixed vegetation. Both evergreen and deciduous trees can be found there. The leaves of these trees fall all year-round. Different micro-organisms living in the soil decompose the fallen leaves increasing the nutrient content of the soil (Rahman et al., 2017). For this reason, relatively more ants seek refuge in the primary forest than the secondary one.

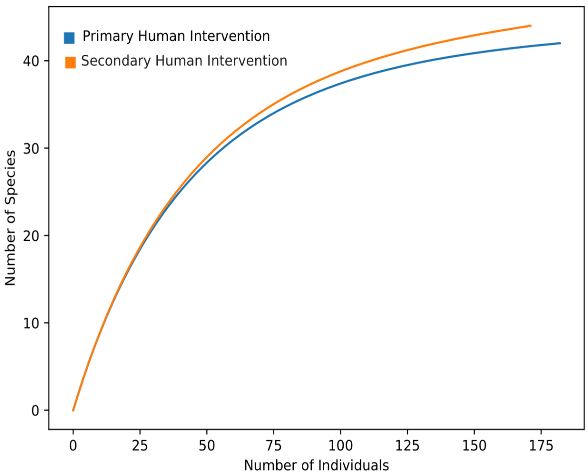
Table 1: Comparison of the Shannon-Wiener Index (*J'*), Evenness Index (*H'*), Effective Number of Index (*ENS*) of the samples found in different areas.

Area	Subarea	Number of Species	Number of Individuals Collected	*H'*	*J'*	*ENS*
Primary	Human-Intervention	42	182	3.56	0.95	35
	Reserved	47	273	3.59	0.93	36
Secondary	Human-Intervention	44	171	3.59	0.95	36
	Reserved	47	217	3.67	0.95	39

The Shannon-Wiener diversity index of each of the subareas (Table 1) is close and has a very high value indicating the high richness and evenness of ant species. The evenness index is almost 1 showing stable communities exist for all the subareas. This is strengthened by the ENS value as we can see the effective number of species is relatively close to the actual number of different species in different subareas.



(a) Rarefaction curve for human-intervened subareas

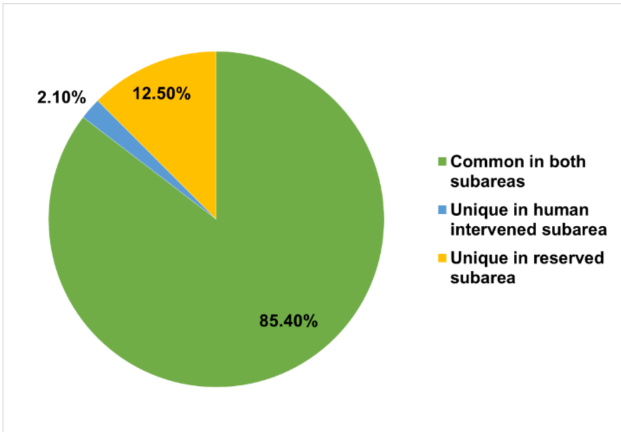


(b) Rarefaction curve for reserved subareas

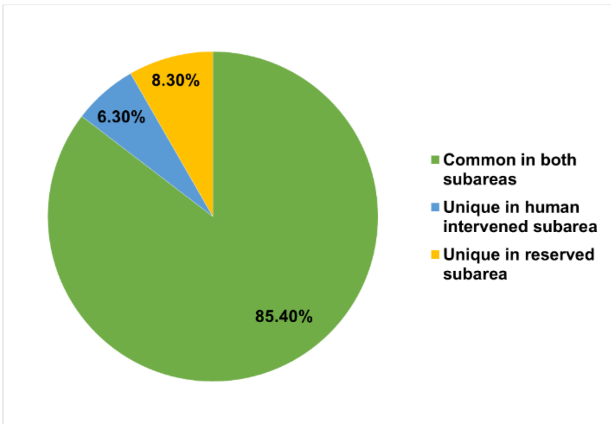
Figure 1: Comparison of rarefaction curves of two subareas in primary and secondary forests

The rarefaction curve (Figure 1) compares the species richness among the similar subareas of the two areas. The species richness of the secondary human intervened subarea is higher than that of the primary human intervened subarea. This can be attributed to partial reforestation by plantation of shrubs in addition to old trees in the secondary area where ant species richness tends to be greater (Watt et al., 2002). However, in both reserved subareas the species richness is almost the same.

Most of the species were common in both Primary and Secondary Forests (Figure 2). However, the majority of the unique species were found in reserved subareas of both forests. This higher number of unique subspecies in the reserved subareas suggest that human intervention plays a key role in depleting the variety in species of ant fauna. On the other hand, reserved subareas with less human activity make them a more habitable place for ants (Floren et al., 2008).



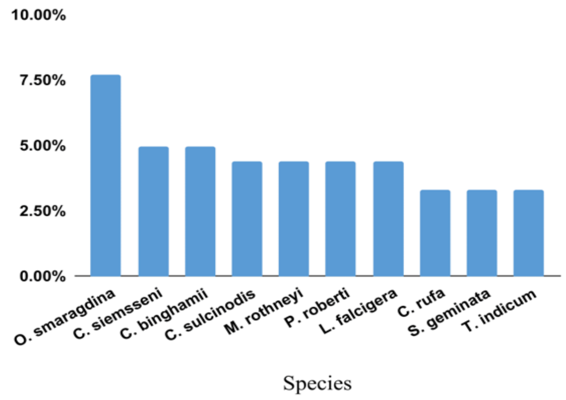
(a) Primary Forest



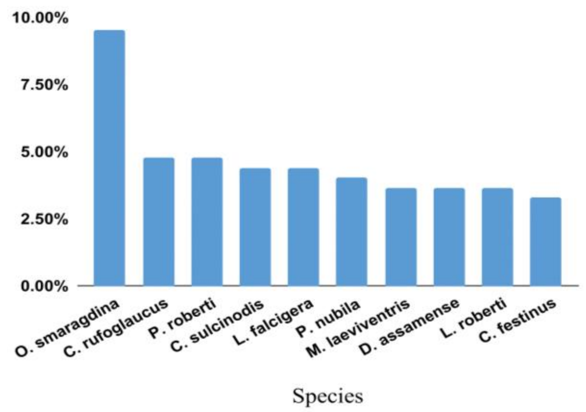
(b) Secondary Forest

Figure 2: Relative proportion of unique and common species in Primary and Secondary Forests

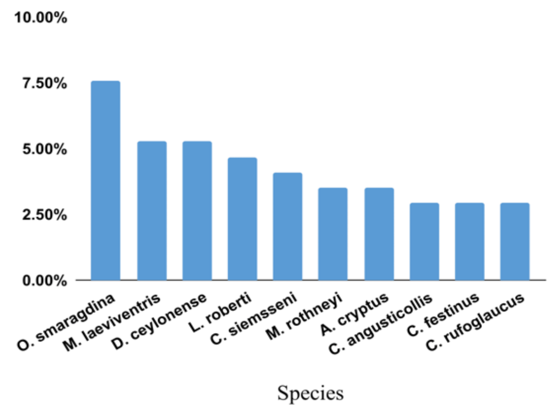
Figure 3 shows the top 10 species in different subareas based on their richness patterns. Overall, 5 species were found in abundance in the primary forest: *C. sulcinodis*, *L. falcigera*, *D. assamense*, *C. binghami*, *T. indicum,* but were rarely found in secondary forest. This can be attributed to the environmental and soil conditions prevalent in the primary forest. The taller trees, rotten wood, and/or moist conditions preferred by the species mentioned can be seen exclusively in the primary forest (Rakotonirina and Fisher, 2014). On the other hand, the secondary forest had its fair share of species that were hardly in the primary forest: *D. ceylonense*, *A. cryptus*, *A. rufus*, *P. pampana*, *C. angusticollis*. Most of these species prefer low vegetation and forage individually on the forest floor found in the secondary forest (Kempf and Brown Jr, 1968).



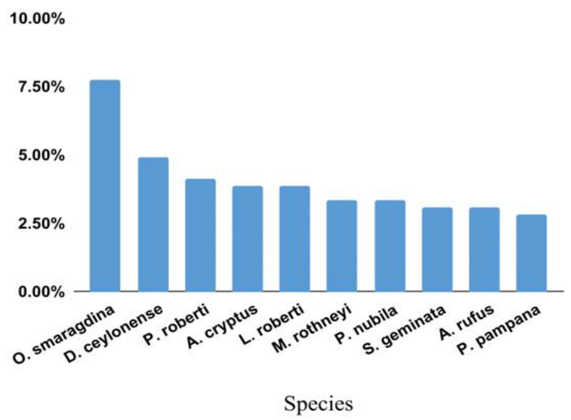
(a) Primary Forest (Human Intervention)



(b) Primary Forest (Reserved)



(c) Secondary Forest (Human Intervention)



(d) Secondary Forest (Reserved)

Figure 3: Relative abundance of the 10 most common species in each forest.

4. Conclusion

Identification of bioindicators for land monitoring and assessment has geared research focus on terrestrial invertebrates. In this regard, ants can be used to determine soil quality, as they play important role in soil formation and provide protection against soil degradation. This relationship makes them ideal for the farmers needing to reliably examine soil biota. Supported by the predictive understanding of community composition related to the disturbance in habitat, ants can be used as effective bioindicators. The data collected in our study can be used in future studies to compare the change in habitat and how it affects the diversity of ants.

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