# Species diversity and functional groups of ants (Hymenoptera: Formicidae) in Jose Rizal Memorial Protected Landscape, Dapitan City, Zamboanga del Norte, Philippines

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**Abstract**. Ants are ubiquitous and have significant implications for the health of the ecosystem. In the Philippines, ant diversity is very high, with many species remaining undescribed. This study was conducted to determine the species diversity and functional groups of the ants in the Jose Rizal Memorial Protected Landscape (JRMPL), Dapitan City, Zamboanga del Norte. Fieldwork was conducted from November 12, 2021, to November 16, 2021. Three sites of secondary dipterocarp forest from Brgy. Talisay, namely: lower forest (LF), middle forest (MF), and upper forest (UF), and an agro-ecosystem (AE) site from Brgy. Sto. Niño employs baiting, pitfall traps, leaf litter sifting, and hand collection methods. Twenty-two species under 19 genera belonging to four subfamilies of the family Formicidae were documented. LF had the highest diversity (H' = 1.891) across sampling sites and a semi-disturbed richness of d = 0.2291. Eight functional groups were classified, with generalized Myrmicinae (GM) being prevalent at the three sites of the secondary dipterocarp forest. GM was abundant at the low disturbance and with the COVID-19 pandemic restricting visitors in JRMPL. Dominant Dolichoderinae (*Dolichoderus thoracicus*) posed a threat to the four sites since it indicated the area was highly disturbed. Four invasive species were present in the area. This implies that the conservation of the protected area should be implemented to maintain its biodiversity.
**Key Words**: generalized Myrmicinae, invasive species, species richness.

**Introduction**. Ants are among the many species that may be found almost anywhere, and their dominance has significant implications for ecosystem health. The services ants contribute to the structure of the environment are through soil ventilation and nutrient cycling, seed dispersal, mutualistic associations with plants and animals, and on evolutionary and ecological scales (Moreau et al 2006; Klimes et al 2012; Dejean et al 2014). Ants are considered ubiquitous, diverse, abundant, and well-described (Batucan & Nuñeza 2013). Consequently, ants predominate in most terrestrial ecosystems, constituting 10% of the tropical rainforest's total animal biomass (Golias et al 2017; Wilson 2000).

The current record of ants in the world has 16 subfamilies, 364 genera, and 14194 species. In the Philippines, there are 10 subfamilies, 101 genera, and 563 species and subspecies of ants (AntWiki 2022). However, many species of ants remain unencountered, or at the least, undescribed (Smith et al 2020). Accordingly, the high diversity of ants in the Philippines results in interesting inventory studies and little of the monotony of encountering the same species over and over again (General & Alpert 2012). Luzon Island has at least 265 species, while Mindanao Island, only slightly smaller in area, has 99 recorded species (General & Alpert 2012).

The majority of the ant surveys in the terrestrial ecosystem are found in different microhabitats on the ground. The ground-dwelling ant community is a good candidate for use in biodiversity inventory and monitoring programs owing to its relative stability, moderate diversity, and sensitivity to microclimate (Agosti et al 2000). In a study of ant diversity in caves, natural barriers prevent ants from colonizing new areas because it is hard for them to cross water bodies, aside from desiccation due to the heat of the sun (Batucan & Nuñeza 2013). In the same habitat, the presence of trees and plants near the entrance of Salawao cave and its exposure to sunlight might be favorable conditions for the species (Figueras & Nuñeza 2013).

Andersen (1995) advocated focusing on functional groups whose abundances vary in proportion to environmental stress and disturbance to detect and analyze changes in the composition of ant communities. This functional group approach offers a promising way of establishing universal norms based on biology rather than specific species identities, as well as the ability to compare global responses (Niemela et al 2000). A global ecology based on functional groups of Hymenoptera: Formicidae concerning stress and disturbance provides a predictive framework for analyzing broad patterns of (1) community composition and behavioral dominance within and between rainforest types, and (2) the responses of rainforest ant communities to disturbance (Agosti et al 2000).

Protected landscapes are sanctuaries for species that thrive in the terrestrial ecosystem. With that, the creation and maintenance of protected areas have been a fundamental strategy to protect biodiversity from such anthropogenic pressures at the local, regional, or global scale (Gaston et al 2008). The Jose Rizal Memorial Protected Landscape (JRMPL) is under Republic Act 11038 or the Expanded National Integrated Protected Areas System (ENIPAS) of 2018) with an area of 439 hectares and a buffer zone of 15 hectares (Official Gazette of the Republic of the Philippines 2018). JRMPL comprises Brgy. Talisay, Brgy. Sto. Niño, and Brgy. Taguilon of Dapitan City, Zamboanga del Norte. The protected area is abundant in indigenous and endemic trees such as Baluno (*Mangifera caesia*), Molave (*Vitex parviflora*), and fire tree (*Delonix regia*); and wild fauna such as the Philippine long-tailed macaque monkey (*Macaca fascicularis philippensis*), Philippine flying dragon (*Draco volans*), Brahminy kite (*Haliastur indus*), Philippine water monitor lizard (*Varanus cumingi*) and many others (Provincial Environment and Natural Resources Office - Zamboanga del Norte 2018). The area is suitable for conducting research on ant diversity since it is a terrestrial ecosystem in which ants predominantly live.

This study provides baseline information on the ant studies at JRMPL. Ants are useful in evaluating management practices for conservation because changes in ant assemblages are usually related to changes in other invertebrate assemblages (Folgarait 1998; Majer et al 2007; Philpott et al 2010). Furthermore, this study helps the Department of Environment and Natural Resources (DENR) Region IX, particularly the Protected Area Superintendent unit (PASu), Dapitan City, in evaluating and preserving the biodiversity of the study area. Specifically, the study determined the microhabitats and possible threats of ants in the area.

## Material and Method

***Description of the study site*.** The study was conducted from November 12, 2021, to November 16, 2021, with a total of five sampling days and 350 total person-hours. The sampling days were shortened due to COVID-19 travel restrictions. A Wildlife Gratuitous Permit (GP) No. IX-PA-04-2021 was issued by the Department of Environment and Natural Resources—Region IX upon the request for the study of ants at JRMPL (Figure 1). The sampling sites were established in secondary dipterocarp forests with three subsites namely lower forest (LF), middle forest (MF), and upper forest (UF) which were located in Brgy. Talisay, and an agro-ecosystem (AE) which was situated in Brgy. Sto. Niño.

The sampling site LF was situated at 8°40’5" North and 123°25’5" East, near the Rizal Park and Shrine and the office of the Protected Area Superintendent unit (PASu), Dapitan City. It had an elevation of 65.83 masl, mountainous terrain, and a partly undulating slope with 40% foliage cover. The transect line measured only 60 meters due to the huge block of rock formation at the dead-end of the site. The air temperature was 26.51°C and the relative humidity of 93.3%. Moreover, LF was covered with tall canopy trees that provided considerable shade. Vines were abundant in LF, as were moderate tree seedlings and shrubs, ferns, emergent trees, and other species of *Pandanus* sp., *Ficus* sp., and *Musa* sp., as well as fruit-bearing trees like jackfruit (*Artocarpus heterophyllus*). Dominant tree taxa were *Pterocymbium tinctorium* and *Dipterocarpus grandifloras*. An ornamental plant, *Caladium* sp., was present moderately on the ground, and 80% of both rocks and mosses covered the site. The soil was wet loamy clay with no humus due to consecutive rainfalls and had a warmer soil temperature of 30°C and a neutral soil pH of 7. Also, a troop of monkeys was observed in the area during the late morning to early afternoon. On-site disturbances were visible at the sampling site such as logging of matured trees and tree saplings; trails in the middle of the site leading to the residential area; the presence of a waiting shed; evident ground erosion; improper garbage disposal such as packages of bath and laundry products found near and floating in the stream; and other food packaging were seen near the waiting shed. The sighted stream had modifications to some of its parts, like the building of a cemented square tub in the middle of the stream for the nearby residents to utilize for bathing and laundry.

The sampling site MF was established a few minutes walk from the LF at 8°40'11" North and 123°24'59" East, with an elevation of 110 masl. The air temperature at the site was 28.7°C and the relative humidity was 92.2%. MF had an undulating slope with a small stream flowing along the 100-m transect line. In addition, it had a difficult trail to pass due to its almost perpendicular inclination with respect to the forest ground. MF had moderate shade compared to LF since trees were averagely distributed to the area. Ferns and fallen logs were rare in MF but abundant in rocks, vines, seedlings, saplings, bryophytes, and plants with the parallel leaf venation. Both the ground cover of seedlings and moss had an 80% density over the area. Mostly mahogany trees (*Swietenia mahagani*), an invasive species was present on the site. *S. mahogani* was mistakenly introduced by the DENR staff in the late 1990s at the JRMPL. MF had a loamy soil type with wet moisture, a soil temperature of 27°C, a soil pH of 6.5-7, a humus covering of 3.4 cm, and a foliage cover of 40%. Observed disturbances were: the logging of trees and some tree saplings; trails connecting the mountain's exit and residential area; man-made stone trails and stairs; and evident garbage on the side of the trails such as liquid bottles and food plastics. A residential house was found on the site, about 30 meters from the transect line.

The sampling site UF was located at 8°40′15" North and 123°25′5" East, near one of the view decks of JRMPL. A 100-meter transect line was established along the mountaineering trail of the site. UF had a partly flat slope with an elevation of 157.5916 masl. The air temperature of the site was 28.7°C with a relative humidity of 85%. The soil was loamy clay and wet, with a warmer soil temperature of 30°C and a neutral soil pH of 7. Fallen logs were 50% rotten and moderately present in 40% of the site. Exposed rocks and water types were absent at UF. Sunlight can easily pass through UF since less shaded trees were abundant in the area. Grasses and sedges were common, along with understory plants such as seedlings and tree saplings. The ground cover comprised 40% grass, tree seedlings, and 40% foliage. The observed dominant trees were *Canthium* sp. and *Pterocarpus indicus*. Ficus plants and moss were 20% rare. The disturbances to the site were the logging of matured trees and skinning of some tree species, multiple trails connecting to the downward route that allows people to exit from the protected area, the establishment of a viewing deck, deep excavation in some parts of the ground, the accessibility of the location to tourists, and garbage left by visitors, such as food packages.

The AE area was situated at 8°41′7" North and 123°25′15" East with an elevation of 264.566 masl and had a mostly flat slope. A 100-m transect line was placed near the road construction where trees had been cleared. The site had an air temperature of 27.3°C and a relative humidity of 84.8%. This sampling site was considered an agricultural area due to the presence of pig livestock and crops such as banana (*Musa* sp.) and coconut tree (*Cocos nucifera*). Coconut husks were piled on the ground. The agro-ecosystem had no shade and was completely open on the majority of the land. This site was rich in moss and ferns, had an abundance of grasses and sedges, seedlings and saplings of trees, grasses, and mosses, rare presence of canopy vines and dominant tree taxa present such as mango tree (*Mangifera indica*), and Bagambang (*Macaranga bicolor*). The leaf litter covered 2 cm in depth and the humus covered 2.5 cm in depth on the site. Soil temperature was 29°C with a pH of 7, and had loamy to wet soil type. The area was covered with 60% exposed rocks. There was no sign of any water type. The distance to the anthropogenic clearing was 50 meters away from the residential areas, and apparent on-site disturbances were the road construction, logging of trees, evidence of grazing (fecal matter of livestock animals present in the location), and piggery.

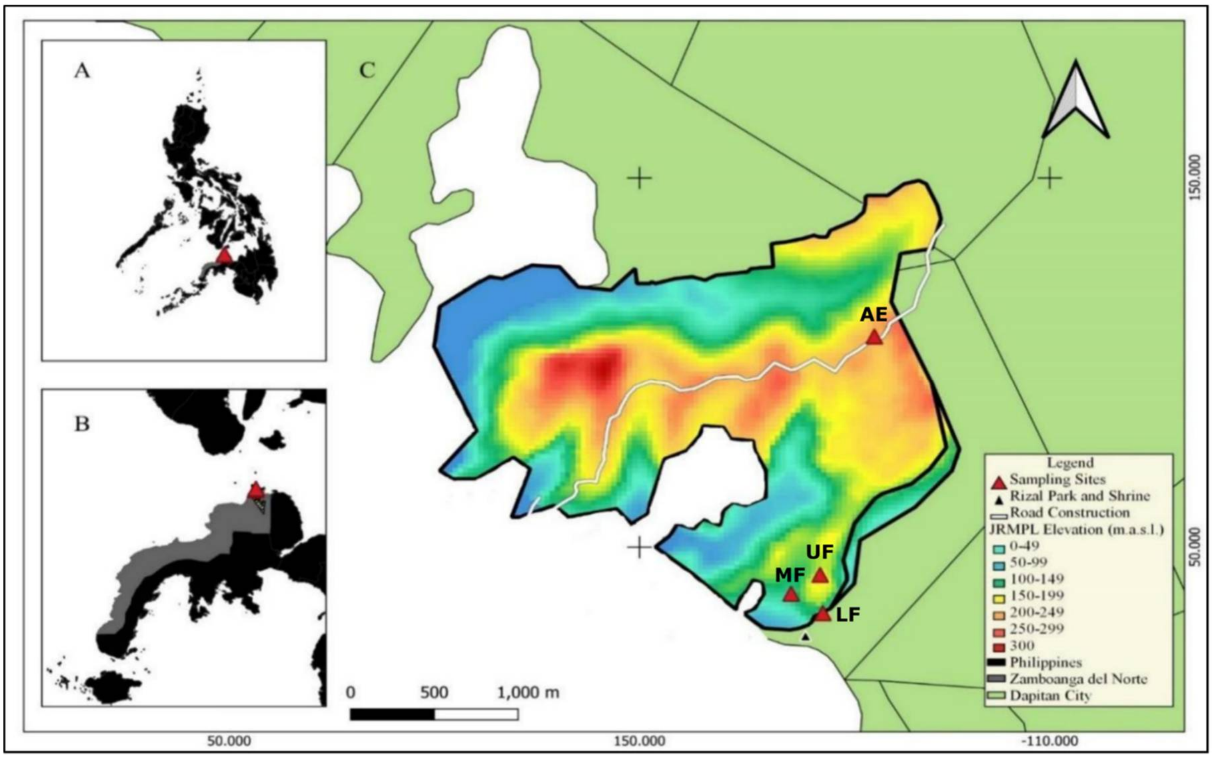


Figure 1. (A) Map of the Philippines, (B) map of Zamboanga del Norte, and (C) the location of the four sampling sites (LF = lower forest, MF = middle forest, UF = upper forest, and AE = agro-ecosytem) at the elevation map of Jose Rizal Memorial Protected Landscape (JRMPL), Dapitan City (PhilGIS 2022).

***Ant sampling***. The ants were collected using four methods, namely: baiting, pitfall trap, leaf litter sifting, and hand collection based on the Ants of the Leaf Litter (ALL) protocol as the standard protocol for collecting ground-dwelling ants (Agosti et al 2000). A 100-m transect line was established at MF, UF, and AE; and a 60-m transect line was placed at LF. The collection methods were conducted at a 10-m distance perpendicular to the transect line in both directions to obtain an allowance of 20-m horizontal to the transect line.

The baiting method was administered to identify the ant species that were attracted to bananas, peanut butter, and tuna. Pitfall traps used were plastic transparent cups with dimensions of 9 cm in diameter and 10 cm in height at the base. The pitfall traps were retrieved after three hours and checked for the presence of ants. Leaf litter sifting was replicated four times within the transect line. A 1x1 $m^2$ quadrat plot was placed on the forest floor, particularly in the rich leaf litter area of the sampling site. The leaf litter inside the 1x1 $m^2$ quadrat plot was gathered, placed in a sifting bag, and sieved several times. Hand collection was especially carried out on ants that live around low plants, between rocks, ground surfaces, mounds, and wood fractures (Hashimoto et al 2001). Furthermore, it was utilized to find solitary ants, armies of ants, and ant colonies. An hour was timed for the hand collection method, and the obtained ant specimens were directly kept in a 20 mL vial with half a fill of 95% ethyl alcohol. The vials containing the ants were labeled with the date, site name, and type of microhabitat.

The ant specimens from the baiting method, pitfall trap, and leaf litter sifting were transferred and labeled in 5 mL vials containing 95% ethyl alcohol. All the ant specimens were sorted out in the laboratory and were examined and taken images using the

AmScope LED 144S MU1000, a stereo microscope with a digital camera projected through the AmScope software. The head, profile, and dorsal positions of the ant specimens were photographed and documented.

Initial ant identification of the specimens was achieved through the dichotomy keys of the published ant taxonomic journals and through comparing the ant images from AntWiki and AntWeb. The initial ant identifications were verified and corrected by a myrmecologist, Dr. David General, from the University of the Philippines, Los Baños – Museum of Natural History. Furthermore, the collected ants were categorized into functional groups based on Hoffman & Andersen (2003). A statistical software, PRIMER v7 (Plymouth Routines In Multivariate Ecological Research) was employed to determine the species diversity, species richness, and evenness value. Shannon-Weiner Index (H') was used to determine species diversity and relative abundance in each sampling site. Margalef richness index (d) measures species richness and it is highly sensitive to sample size although it tries to compensate for sampling effects (Magurran 2004). Pielou's evenness (J') calculates the species evenness by measuring diversity along with species richness. These biodiversity indices were calculated to determine the rarity and commonness of species in a community and the community structure. Also, Jaccard distance was measured to quantify two dissimilar sets.

## Results and Discussion

***Species composition***. A total of 2,584 ant specimens belonging to 22 species, 19 genera, and four subfamilies were identified at JRMPL (Table 1). Subfamily Myrmicinae had the highest number of species, accounting for 11 species; Subfamily Formicinae and Subfamily Ponerinae with four species each; and Subfamily Dolichoderinae with three species.

*Dolichoderus thoracicus, Carebara diversa*, *Crematogaster* sp. 1, and *Odontomachus simillimus* were present in the four sites. Two specialist predators: *Brachyponera* sp. and *Odontoponera denticulata* were present in sites LF, MF, and UF that were categorized as secondary dipterocarp forests and had no records in AE. These ants had relatively little interaction with other ants due to their specialist diet, large body size, and small colony size (Hoffman & Andersen 2003). The forest cover of sites LF, MF, and UF was higher than AE which allows these two specialized predators to occupy the habitat since the food source is available and easy to locate. In addition, the habitat structure of AE comprised crop-producing plants and few trees were accounted.

The species with the highest relative abundance was *D. thoracicus* with 76.9% (AE) followed by *Crematogaster* sp. 1 with 71.9% (MF). *D. thoracicus* was the only dominant Dolichoderinae and was characterized by highly active, abundant, and aggressive species that favor hot and open habitats and exert a strong competitive influence on other ants (Hoffman & Andersen 2003). It was observed by General & Alpert (2012) that *D. thoracicus* was common in urban and highly disturbed areas.

Four invasive species, namely: *Anoplolepis gracilipes*, *Solenopsis geminata*, *Tapinoma melanocephalum*, and *Trichomyrmex destructor* were accounted for this study. These invasive species can damage seedlings and disrupt pollination, and the economic and ecological repercussions of their introduction can be costly (Sinu et al 2017; Hansen et al 2008). Human disturbance frequently facilitates invasive ant species that have colonizing mechanisms well-adapted to humans (Graham et al 2004), and they have a negative impact on native ant species and decrease species richness (Holway et al 2002). The presence of invasive ants can dominate the area and threaten the local ant species.

The leaf litter sifting method had the least obtained species from the four sampling sites. Baits, pitfall traps, and hand collection had a closer value of species richness, accounting for 13-14 species in each method. *C. diversa*, *D. thoracicus*, and *Nylanderia* sp. were found in all the methods for ant collection. For the baiting method, banana bait attracted eight species (*A. gracilipes*, *C. diversa*, *D. thoracicus*, *Monomorium* sp., *Odontomachus* sp., *Pheidole aglae*, *Technomyrmex* sp., and *T. destructor*), peanut butter bait had accumulated 10 species (*Calyptomyrmex* sp., *C. diversa*, *Crematogaster* sp. 1, *D. thoracicus*, *Nylanderia* sp., *O. denticulata*, *P. aglae*, and *T. melanocephalum*, *Tetramorium* sp., and *T. destructor*) and tuna bait was consumed by four species of ants (*A. gracilipes*, *C. diversa*, *Crematogaster* sp. 1, and *D. thoracicus*).

Table 1

Species composition and functional groups of ants found in Jose Rizal Memorial Protected Landscape

| *Subfamily* | *Species* | *Functional group (Hoffman & Andersen 2003)* | *Brgy. Talisay (Secondary dipterocarp forest)* | | | *Brgy. Sto. Niño (Agro-ecosystem (AE))* |
|---|---|---|---|---|---|---|
| | | | *Lower forest (LF)* | *Middle forest (MF)* | *Upper forest (UF)* | |
| Dolichoderinae | *Dolichoderus thoracicus* | Dominant Dolichoderinae | 24 (5.13) | 18 (3.72) | 27 (9.54) | 1055 (76.9) |
| | **Tapinoma melanocephalum* | Opportunists | 1 (0.21) | - | 6 (2.12) | - |
| | *Technomyrmex* sp. | Opportunists | 1 (0.21) | - | - | - |
| Formicinae | **Anoplolepis gracilipes* | Cryptic species | 14 (2.99) | - | 14 (4.95) | - |
| | *Camponotus* sp. | Subordinate Camponotini | - | - | - | 7 (0.51) |
| | *Nylanderia* sp. | Subordinate Camponotini | 17 (3.63) | - | - | 11 (0.80) |
| | *Oecophylla smaragdina* | Tropical climate specialists | - | - | 21 (7.42) | - |
| Myrmicinae | *Calyptomyrmex* sp. | Generalized Myrmicinae | - | 30 (6.2) | 1 (0.35) | - |
| | *Carebara diversa* | Generalized Myrmicinae | 174 (37.2) | 78 (16.1) | 185 (65.4) | 40 (0.91) |
| | *Crematogaster* sp. 1 | Generalized Myrmicinae | 34 (7.26) | 348 (71.9) | 2 (0.71) | 15 (1.09) |
| | *Crematogaster* sp. 2 | Generalized Myrmicinae | - | - | - | 7 (0.51) |
| | *Monomorium* sp. | Generalized Myrmicinae | - | - | - | 213 (15.5) |
| | *Pheidole aglae* | Generalized Myrmicinae | 9 (1.92) | 4 (0.83) | - | 5 (0.36) |
| | *Pheidole* sp. | Generalized Myrmicinae | - | - | - | 1 (0.07) |
| | **Solenopsis geminata* | Hot climate specialists | 1 (0.21) | - | 2 (0.71) | 10 (0.73) |
| | *Strumigenys* sp. | Generalized Myrmicinae | - | - | 2 (0.71) | - |
| | *Tetramorium* sp. | Generalized Myrmicinae | 10 (2.14) | 1 (0.21) | - | 1 (0.07) |
| | **Trichomyrmex destructor* | Generalized Myrmicinae | 118 (25.2) | - | - | - |
| Ponerinae | *Brachyponera* sp. | Specialist predators | 8 (1.71) | 1 (0.21) | 4 (1.41) | - |
| | *Odontoponera denticulata* | Specialist predators | 17 (3.63) | 2 (0.41) | 6 (2.12) | - |
| | *Odontomachus simillimus* | Specialist predators | 21 (4.49) | 2 (0.41) | 1 (3.89) | 3 (0.22) |
| | *Odontomachus* sp. | Specialist predators | 6 (1.28) | 0 | 2 (0.71) | 4 (0.29) |
| | Total of individuals: 2,584 | | 455 | 484 | 273 | 1372 |
| | Total no. of species: 22 | | 15 | 9 | 13 | 13 |
| | Total no. of invasive species: 4 | | 4 | 0 | 3 | 1 |

*Invasive species based on www.antweb.org, () relative abundance.

It was found that *C. diversa* and *D. thoracicus* were both present in the three baits traps. The studies of both Yanoviak & Kaspari (2000) and Kaspari & Yanoviak (2001) compared the foraging preference of ants attracted to bait stations containing protein, carbohydrates, and water in the canopy and on the litter surface. When species were classified according to their preferences, a greater proportion of arboreal species preferred protein baits, and a greater proportion of terrestrial species preferred carbohydrate baits (Hahn & Wheeler 2002).

***Biodiversity indices*.** Table 2 shows that LF site exhibited by the most species recorded, with 15 different species while UF and AE both contained 13 species, whereas MF had the lowest species number, with only nine species. In terms of diversity, LF accumulated the highest diversity of H' = 1.891 with a richness of d = 2.287.

In MF, the diversity and richness values were H' = 0.9367 and d = 1.294 respectively, which both indicate low diversity and low species richness. The rarely fallen logs, few tree taxa, presence of invasive species *S. mahagani*, and a residential home on the site were the factors influencing low diversity indices for the MF. With these factors, microhabitats of ants can be lesser to be found in the area. It has been demonstrated that a more complex vegetation structure results in a much higher availability of microhabitats for different ant groups, particularly when there are large trees present (Quiroz-Robledo & Valenzuela-González 1995; Schonberg et al 2004; Philpott et al 2010; Rojas et al 2014). Few ant species tolerate the disturbances in the area and perhaps moving to a different area with a suitable environment and less disturbed can be the option for ants. UF and AE had the same number of species recorded. This indicates that both sites had a similar environment for the ants to thrive. Specifically, both sites had similar shades, absence of water type, soil data, and tree taxa.

Based on the habitat structure of the sites LF, MF, and UF, on-site disturbances were apparent such as the nearby homes and scattered plastic garbage in the area that can generally affect the low diversity of ants across sampling sites in the forest. Moreover, the shortened sampling days and modified ant collection methods can also be factors to obtain a low diversity of the site. LF had the most number of species with a balanced evenness value of d = 2.287. Silva et al (2011) noted that ant species density increased with an increasing number of leaves and a number of leaf morphotypes but was also influenced by plot location factors such as plant species richness, vegetation structure, and environmental conditions.

Table 2

Biodiversity indices of ants in four sampling sites at JRMPL

| *Site* | *S* | *N* | *d* | *H'* | *J'* |
|---|---|---|---|---|---|
| Lower forest (LF) | 15 | 455 | 2.287 | 1.891 | 0.6984 |
| Middle forest (MF) | 9 | 484 | 1.294 | 0.9637 | 0.4263 |
| Upper forest (UF) | 13 | 273 | 2.139 | 1.257 | 0.4901 |
| Agro-ecosystem (AE) | 13 | 1372 | 1.661 | 0.8335 | 0.3249 |

Note: S = total species; N = total number of individuals; d = Margalef richness index; H' = Shannon-Wiener index; J'= Pielou's evenness.

Bait and pitfall trap methods had a high dissimilarity value based on their obtained Jaccard distance of 0.933 and 0.928, respectively (Table 3).

The variety of species occurrences was high and one species was common in both methods which are *D. thoracicus* in bait and *C. diversa* in a pitfall trap. *C. diversa* occurred in both sites using the methods of pitfall trap, leaf litter, and hand collection. The abundance of ant foragers at baits may help to measure ecological and behavioral dominance and provide a general measure of ant foraging efficiency (Greenslade & Greenslade 1971). Moreover, the species most likely to visit baits are trophic generalists (Agosti et al 2000). Similar to baiting, the ant obtained from pitfall traps provides a measure of species importance in a community by integrating both forager attributes and colony dispersion patterns (Greenslade 1973). The pitfall trap may be used to census the ants foraging on soil and leaf litter (Agosti et al 2000).

Table 3

Dissimilarity of species collected using the four methods

| *Ant collection method* | *Secondary dipterocarp forest (LF, MF, UF)* | *Agro-ecosystem (AE)* | *All sites* | *Jaccard distance* |
|---|---|---|---|---|
| Bait | 13 | 2 | 1 (*D. thoracicus*) | 0.933 |
| Pitfall trap | 9 | 5 | 1 (*C. diversa*) | 0.928 |
| Leaf litter | 5 | 4 | 2 (*C. diversa*, *S. geminata*) | 0.778 |
| Hand collection | 9 | 5 | 3 (*C. diversa*, *D. thoracicus*, *Crematogaster* sp. 1) | 0.786 |

***Functional groups***. Eight functional groups were found from the four sampling sites. These include dominant Dolichoderinae (DD) with one species, subordinate Camponotini (SC) with two species, tropical climate specialists (TCS) with one species, cryptic species (CR) with one species, opportunists (OP) with two species, generalized Myrmicinae (GM) with ten species, hot climate specialists (CS) with one species and specialist predators (SP) with four species (Figure 2).

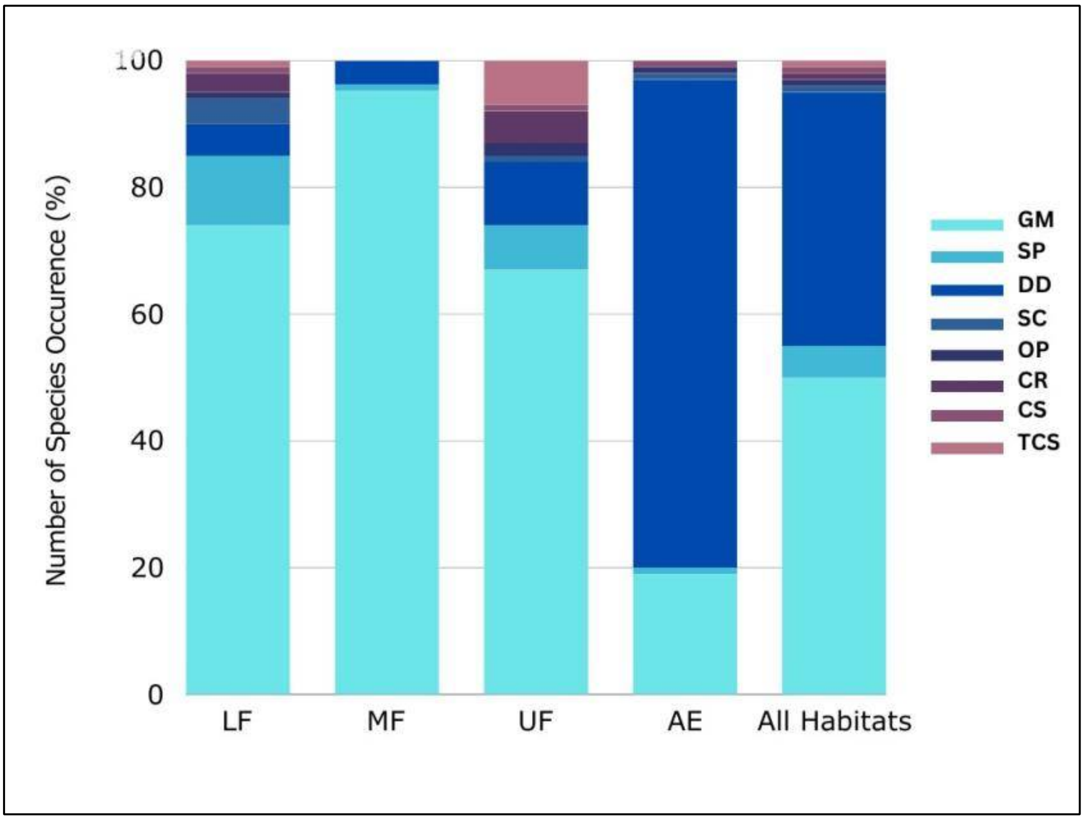


Figure 2. Proportional distribution of functional groups from the accumulated specimens on the four habitats.

Differences in functional group composition among ant assemblages from the habitats sampled suggested that the observed variation in species composition results in part from differences in the climate-related stress and competition dynamics in those habitats (Miguelena & Baker 2019). All the sites in the secondary dipterocarp forest were dominated by GM. A year and a half after the COVID-19 pandemic, the JRMPL was prohibited to accept tourists and resulting in less disturbance in the area. LF, MF, and UF were characterized as secondary dipterocarp forests with a variety of tree taxa. The reduction of habitat complexity by human activities greatly affects the abundance of resources as well as microclimatic and abiotic conditions for ants (Groc et al 2014). DD was absent in LF, MF, and UF. The absence of DD competitors allows the progressive GM to increase in undisturbed areas (Gomez et al 2003). Moreover, the high abundance of GM was associated with their higher tolerance to environmental disturbances (Andersen 2000).

Interestingly, TCS with one species (*O. smaragdina*) was only found in UF. TCS distribution is centered on the humid tropics and occurs in habitats where DD is generally not abundant (Hoffman & Andersen 2003). AE comprised a large portion of DD. The area was considered an agricultural area and near the road construction where trees had been cleared which was preferred by DD. DD is an abundant, highly active, and aggressive species that favor hot and open habitats, and exerts a strong competitive influence on other ants (Hoffman & Andersen 2003). Also, lesser trees populated the site, and apparent clearing resulted in open ground for the DD to forage. In agroecosystems, agricultural intensification, human disturbance, and land-use change have a negative impact on ant diversity and its composition (Gibb & Hochuli 2003; Gómez et al 2003).

***Microhabitats***. Thirteen species of ants were collected using the hand collection method with different observed microhabitats (Table 4). The different microhabitats were observed in the four sites with varying micro-climate and food availability depending on the vegetation and disturbance of the site. The majority of the species were obtained on the ground floor and tree trunk. *C. diversa* was found on the ground floor and on rocks. *O. simillimus* and *D. thoracicus* were both found on the tree trunk and ground floor. Ants were found in plant litter, rotten logs, and leaf bases. These species build their nests on flat rocks (Holldobler & Wilson 1994) or termite nests (Leponce et al 1999), in tree trunks (Schutte et al 2007), around roots (Adams & Longino 2007), or in the canopy of living trees (Longino & Nadkarni 1990; de Oliveira et al 2015).

A more complex vegetation structure results in a much higher availability of microhabitats for different ant groups, particularly when there are large trees present (Quiroz-Robledo & Valenzuela-González 1995; Schonberg et al 2004; Philpott et al 2010; Rojas et al 2014). A study conducted by McGlynn & Kirksey (2000) concluded that ants may select a microhabitat based on the type of resource that is frequent in that microhabitat.

Table 4

Observed ant species on different microhabitats

| *Species* | *Tree trunk* | *Plant litter* | *Ground floor* | *Rock* | *Rotten log* | *Leaf base* |
|---|---|---|---|---|---|---|
| *Anoplolepis gracilipes* | – | + | – | – | – | – |
| *Camponotus* sp. | + | – | – | – | – | – |
| *Carebara diversa* | – | – | + | + | – | – |
| *Crematogaster* sp. 1 | – | – | – | – | – | + |
| *Crematogaster* sp. 2 | + | – | – | – | – | – |
| *Dolichoderus thoracicus* | + | – | + | – | – | – |
| *Odontomachus simillimus* | + | – | + | – | – | – |
| *Odontomachus* sp. | – | – | + | – | – | – |
| *Odontoponera denticulata* | – | – | + | – | – | – |
| *Oecophylla smaragdina* | + | – | – | – | – | – |
| *Nylanderia sp.* | – | + | – | – | – | – |
| *Pheidole aglae* | – | – | + | – | – | – |
| *Tetramorium* sp. | – | – | – | – | + | – |

Note: + observed, - unnoticed.

***Possible threats***. Litters on the ground were the common threats of ants in the four sampling sites. Most of the litters came from the tourists of JRMPL before the pandemic. The left litters were scattered on the forest floor and can be seen most frequently on the trails of JRMPL. Ants forage in the forest floor and live in the soil that is threatened by the disturbance from waste products that were present in the site. Habitat disturbance can cause decreasing ant species richness and alter the composition of ant communities (Schoereder et al 2004). Different litters were observed from the plastic bottles up to the food packages. This posed a threat to ant communities and their microhabitat if not resolved.

**Conclusions**. Twenty-two species from 19 genera belonging to four subfamilies of the family Formicidae were accounted for in the Jose Rizal Memorial Protected Landscape. Generally, species diversity ranges from 0.8335 to 1.891 of all sampling sites was considered very low. The degree of disturbance and habitat structure determines the diversity of the sampling sites. Also, the vegetation type of each site affects the abundance and diversity of species since it serves as a microhabitat and food for the ants. Eight functional groups were classified, with generalized Myrmicinae being prevalent at the three sites of the secondary dipterocarp forest. GM was abundant at the low disturbance and with the COVID-19 pandemic restricting visitors in JRMPL. Dominant Dolichoderinae (*D. thoracicus*) posed a threat to the four sites because it indicated that the area was highly disturbed. Four invasive species were recorded in the study, and thus continuous conservation should be implemented in the protected area.

Weekly forest clean-up is recommended for the protected area since numerous waste items were found during the sampling. Tourists visiting the protected area are advised to follow the rules, especially in disposing of their waste. More sampling efforts in the area could result in a high species richness of ants. DNA barcoding should be employed to identify the ants up to the species level.

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**Conflict of interest**. The authors declare that there is no conflict of interest.

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