COMMUNITY STRUCTURE OF THE ANTS (Hymenoptera: Formicidae) IN WAY SEKAMPUNG RESORT, BATUTEGI PROTECTED FOREST, LAMPUNG PROVINCE

(Undergraduate Thesis)

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ABSTRAK

STRUKTUR KOMUNITAS SEMUT (Hymenoptera: Formicidae) DI RESORT WAY SEKAMPUNG HUTAN LINDUNG BATUTEGI PROVINSI LAMPUNG

oleh

MUHAMMAD YUSUF AL FAZA

Semut sebagai kelompok hewan darat dengan jumlah individu paling dominan di daerah tropis memiliki peran dalam interaksinya dengan tumbuhan atau serangga lain, serta keberadaannya dipengaruhi oleh faktor lingkungan. Semut dapat ditemukan di berbagai habitat, salah satunya di Hutan Lindung Batutegi. Tujuan dari penelitian ini untuk mengetahui indeks keanekaragaman, kelimpahan relatif, dominansi, kekayaan, kesamaan, dan kemerataan spesies semut, faktor biotik dan abiotik yang memengaruhi keberadaan semut, dan perbandingan antar metode pengambilan sampel semut berdasarkan jumlah individu dan spesies. Penelitian dilakukan pada Januari sampai Februari 2024. Semut dikoleksi dengan metode *pitfall trap* dan *hand-collecting* pada enam habitat berbeda (sempadan sungai, semak belukar, interior hutan, kebun rapat, kebun jarang, dan tepi irigasi). Data jumlah individu dan spesies semut dianalisis menggunakan indeks keanekaragaman Shannon-Wiener (H’), kelimpahan relatif (IKR), dominansi Simpson (D), kekayaan Margalef (R), kesamaan Jaccard (SJ), dan kemerataan Pielou (E). Analisis asosiasi semut dengan makrofauna lain dilakukan dengan tabel kontingensi 2x2, uji *chi-square*, dan indeks asosiasi Ochiai (IO). Korelasi antara faktor abiotik dengan indeks keanekaragaman, kelimpahan relatif, dan kemerataan semut dilakukan dengan analisis korelasi Pearson. Sebanyak 1994 individu dari 84 spesies semut telah diidentifikasi. Keanekaragaman spesies semut tergolong sedang (H’ = 2,963), dominansi spesies rendah (D = 0,127), kekayaan spesies tinggi (R = 10,92), kemerataan spesies labil (E = 0,67), dan kesamaan spesies antar habitat rendah dengan nilai SJ berkisar antara 0,13 – 0,40. Nilai IKR tertinggi ada pada *Anoplolepis gracilipes* sebesar 32,29%. Faktor biotik yang memengaruhi semut yaitu adanya asosiasi semut dengan Lycosidae sebagai predator dan Gryllidae sebagai mangsa. Faktor abiotik yang sangat memengaruhi keberadaan semut adalah pH tanah dan kelembapan tanah. *pitfall trap arboreal* unggul dalam perolehan jumlah spesies dan *pitfall trap terestrial* unggul dalam perolehan jumlah individu, namun *hand-collecting* tetap perlu dilakukan untuk memperoleh semut yang tidak tertangkap pada *pitfall trap*. Implikasi dari penelitian ini adalah perlunya menjaga kelembapan tanah untuk mencegah menurunnya keanekaragaman spesies semut dan mencegah masuknya spesies semut kosmopolitan lain yang berpotensi merugikan ekosistem.

Kata kunci: semut, komunitas semut, ekologi semut, *pitfall trap*, Hutan Lindung Batutegi

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MUHAMMAD YUSUF AL FAZA

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LETTER OF AUTHENTICITY OF UNDERGRADUATE THESIS

The undersigned:

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hereby declare that my undergraduate thesis titled:

"COMMUNITY STRUCTURE OF THE ANTS (Hymenoptera: Formicidae) IN WAY SEKAMPUNG RESORT, BATUTEGI PROTECTED FOREST, LAMPUNG PROVINCE"

Is truly and entirely my own work, created in accordance with the applicable norms and academic ethics. Furthermore, I do not object to use of some or all of the data from this undergraduate thesis by faculty members and/or the study program of publication purposes, provided that my name is mentioned. If it is later proven that my statement is untrue, I am willing to accept academic sanctions, including the revocation of my bachelor's degree, as well as legal consequences.

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BIOGRAPHICAL SKETCH

The author was born in Bandarlampung on June 18th, 2002 as the first child of three siblings of Taufanuddin and Rita Dewi Rustanti. The author received his first education at TK Pratama Kids in 2007, then continued his education at SDN 2 Rawa Laut in 2008. The author continued his education at SMPN 8 Bandarlampung in 2014, then studied at SMAN 1 Bandarlampung in 2017 and graduated in 2020.

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Bandarlampung, July 22, 2024
The author

Muhammad Yusuf Al Faza

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I. INTRODUCTION

1.1. Background Research

Insects are one of the interesting aspects in biology as one of the most abundant fauna and have many species throughout the world. According to Jurzenski et al. (2012) there is still little utilization of insect species that have the potential to be used as biological indicators for assessing ecosystem changes.

Ants as the most abundance terrestrial animals in tropical areas have an important role in the ecosystem, such as predators, herbivores, detritivores, and scavengers. The specific role of ants for each type in their interactions with plants or other insects, one of which is as prey for insectivores. Ants have developed into the most dominant animals in terrestrial ecosystems. According to Holldobler and Wilson (1990) in Rizal et al. (2020) of the 750,000 species of insects in the world, 9,500 or 1.27% of them are ants. The ant population in the world is quite stable throughout the seasons and years. The abundant and consistent presence makes ants a significant insect colony in the ecosystem. Ants are often used as biological indicators in various environmental assessment programs, such as forest fire evaluations, impacts on vegetation, logging activities, mining, waste disposal, and land use factors (Wang et al., 2000).

Ants have an important ecological role in forest ecosystems, especially in the soil element cycle and soil aeration. Ants have a reciprocal relationship with other organisms and play an important role as invertebrate predators in the forest (Watanasit and Bickel, 2005). Because the ant community has intensive activities in digging continuously in the soil, this makes ants have an important role in the mineralization process (Bruhl et al., 1999 in Yulminarti, 2021).

Based on the Decree of the Minister of Forestry Number SK.68/MenhutII/2010, the Batutegi Protected Forest is one of Indonesia's protected forests managed by the Protected Forest Management Unit (Kesatuan Pengelolaan Hutan Lindung) in the Batutegi area. There are various types of fauna in the Batutegi Protected Forest, including 55 species of mammals, 54 species of reptiles, 75 species of insects, and 245 species of birds that have been successfully identified. There are 346 species in 59 plant families that grow in the Batutegi Protected Forest. Arecaceae is the most commonly found family in the Way Sekampung Resort, including *Oncosperma horridum*, *Cocos nucifera*, *Calamus caesius*, *and Daemonorops longipes*. In addition, there is *Rafflesia arnoldii* as one of the rare plant species (Alfandy et al., 2020; Huda, 2022).

The existence of ant species in general cannot be separated from the existence of animals, plants, and the environment in their habitat, which are interconnected with each other. The existence of ants on the ground surface (terrestrial) and tree strata (arboreal) is quite diverse because these two areas have the availability of diverse food sources (Gusmasri et al., 2018).

This study was conducted to determine the structure of the ant community in the Batutegi Protected Forest of Lampung Province in various types of habitats based on ecological indices, associations with other macrofauna, correlations between ants and environmental factors, and compares between three different ant sampling methods.

1.2. Research Purposes

This study aims to:

1. Find out the abundance and species of ants in the Batutegi Protected Forest;
2. Analyze the diversity, relative abundance, richness, similarity, evenness, and dominance of ant species in the Batutegi Protected Forest;
3. Analyze the biotic and abiotic factors that influence the presence of ants in the Batutegi Protected Forest; and
4. Compare between three different ant sampling methods based on the number of individuals, number of species, and the simiilarity of the ant species obtained.

1.3. Benefit of the Research

The result of this study is expected to provide information of ant diversity, abundance, richness, similarity, and evenness in the Batutegi Protected Forest, the relationship between ants and biotic and abiotic factors, and the effectiveness of ant sampling methods that can be used as references for research and utilization of ants and soil arthropods in the future.

1.4. Theoretical Framework

Batutegi Protected Forest is thought to be a natural habitat for various types of ants to live. There are various types of habitats that support the life of ants, including riverside, bushes, forest canopy, dense farm, sparse farm, and irrigation side, because they are suitable for ants to nest and forage. The Batutegi Protected Forest area is thought to be an area with a high abundance of ant species because there are abundant water sources, various types of animals, and fruits and flowers on plants. To obtain data on community structure, indices were used on the number and species of ants found, including the Shannon-Wiener diversity index, relative abundance index, Simpson dominance index, Margalef richness index, Jaccard similarity index, and Pielou evenness index with tabulation using Microsoft Excel 2010. To obtain data on the association of ants with other macrofauna tribes, a 2x2 contingency table, chi-square test, and Ochiai index were used. To obtain data on the correlation of abiotic factors with the ant ecological index, Pearson correlation analysis was used.

II. LITERATURE REVIEW

2.1. Ant (Formicidae)

2.1.1. Ant Classification

According to ITIS (Integrated Taxonomic Information System) (2023), the classification of ant is as follows:

Kingdom	: Animalia
Phylum	: Arthropoda
Class	: Insecta
Order	: Hymenoptera
Family	: Formicidae (Latreille, 1809)

2.1.2. Ant Morphology

Ants body is divided into three large parts, the head, mesosoma, and gaster, with one small part (petiole) between the mesosoma and gaster (Borror et al., 2005). The exoskeleton in ants is composed of chitin. On the head, there is a pair of segmented and jointed antennas, as sensory organs that detect chemical compounds, touch, and vibrations (Taszakowski et al., 2023). A pair of mandibles in ants generally function as defense and clamping. Ants have compound eyes consisting of many lenses, collectively forming a mosaic image in their vision, and have three simple eyes (ocelli) as as light-detecting organs and natural compasses connected to the compound eyes. Ants rely more on antennas as sensory organs than eyes (Schwarz et al., 2011).

The mesosoma is the middle part of the ant, consisting of the thorax and propodeum (the first segment of the abdomen) which are fused. The mesosoma has three pairs of jointed legs. The leg structure of ants varies from species to caste level. At the species level, differences in the structure of ant legs are due to adaptation to the habitat, while at the caste level they are due to differences in roles in the colony (Endlein and Federle, 2015). The petiole is part of the abdomen in the form of a segment that is flatter than the gaster, consisting of one or two nodes with varying shapes depending on the type (Lapolla and Barden, 2018). The morphological structure of ants can be seen in Figure 1.

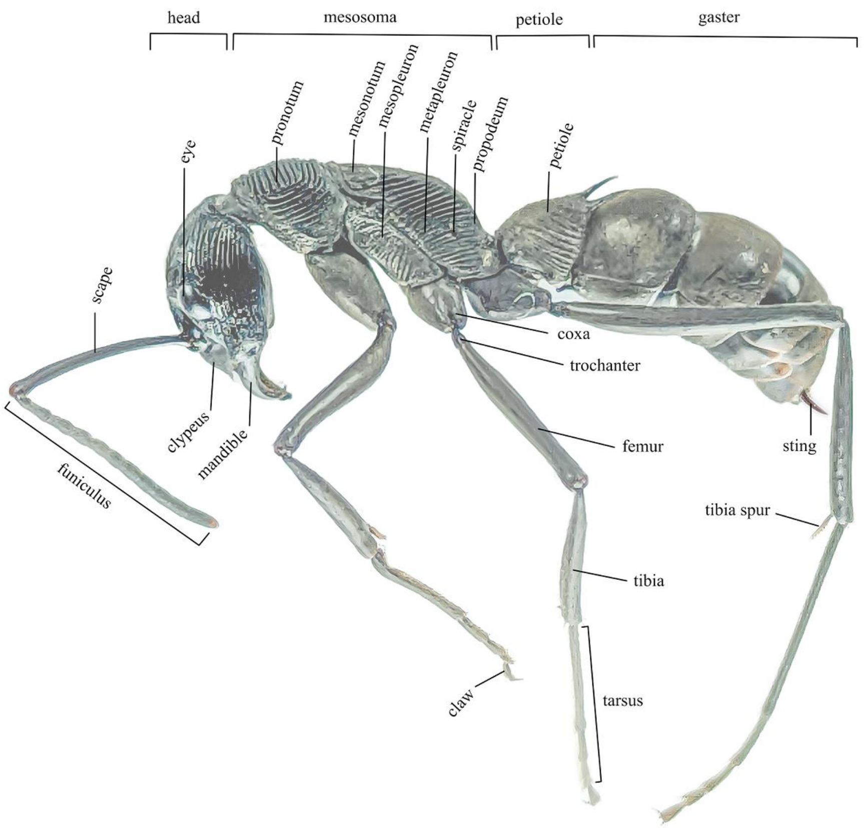

Figure 1. Ant morphology.

Some types of ants have two pairs of wings in the queen and male castes which function to find mates and suitable habitats for nesting. The wings of the queen ant can be removed or remain attached if it has been fertilized by the male (Ito et al., 2021).

2.1.3. Ant Anatomy

Ants have a complex internal organ system that regulates digestion, circulation, reproduction, and sensing. The digestive organs in ants consist of the crop, proventriculus, midgut, hindgut, and rectum. The crop functions as a temporary storage place for food before being channeled to the proventriculus. The proventriculus functions as a valve or filter that regulates the entry of food into the midgut. The midgut functions to absorb nutrients in food obtained through the catabolism process by digestive enzymes. The remaining food that has been processed in the midgut will be channeled to the hindgut to absorb water and ions that have not been absorbed in the midgut, and the formation of feces which will then be excreted through the rectum (Figure 2) (Zheng et al., 2021).

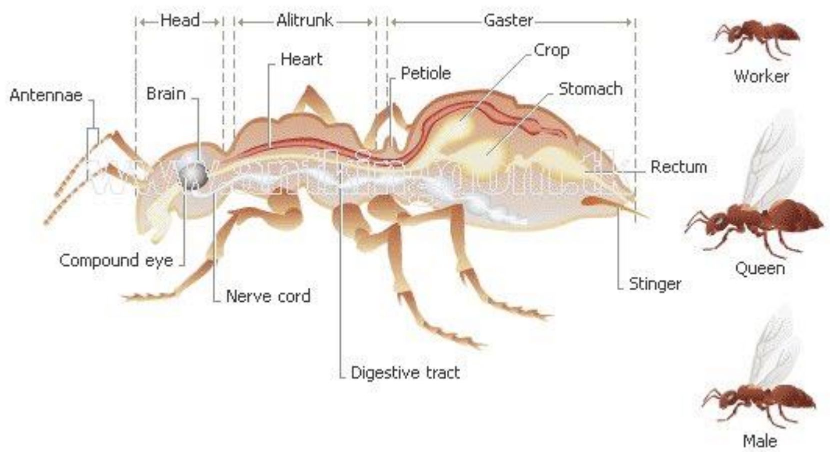

Figure 2. Ant anatomy (Laffitte, 2005).

The organs in the circulatory system and blood circulation in ants consist of the trachea, aorta, vessels, and heart. Ants obtain oxygen through the trachea which is then bound to the hemolymph. The heart in ants is tube-shaped, functioning to flow hemolymph to the aorta which is then distributed throughout the body. The organs in the ant nervous system consist of the brain, ganglia, sensory organs (eyes, antennae), and nerve fibers. The brain functions as a center for processing sensory information, regulating physiological responses and behavior. Ganglia in ants are spread across each body segment which functions to coordinate certain activities or reflexes that are connected to nerve fibers in the sensory and motoric organs (Falibene et al., 2011).

2.1.4. Ant Life Cycle

As holometabolous animals, ants undergo complete metamorphosis. In general, the life phase of ants begins from eggs. Eggs hatch 1-3 weeks after oviposition. Ant larvae do not have limbs so they are immobile and require the help of the queen or worker ants to obtain nutrition. Before entering the pupal phase, ant larvae shed their skin 3-4 times with a duration of 2-3 weeks. In the pupal phase, reorganization and maturation of organs occur in ants for 1-3 weeks to reach the imago phase (Mongkolsamrit et al., 2012; Verza et al., 2017).

The imago phase of ants is divided into two types, fertile and sterile type. In the fertile type, wings are formed on the imago, while in the sterile type, wings are not formed. The imago phase in ants has variations that will determine the role of the ant in the colony (Mongkolsamrit et al., 2012). Fertile imago is divided into two, queen (fertile female) and male. The queen can survive up to 20 years, while males live for 2-3 months. Sterile imago (workers) live for 1-3 years (Kramer et al., 2016).

2.1.5. Social Structure and Behavior of Ants

As social insects, ant colonies have an organized castes. The social structure of ants according to Patel and Bhatt (2020) is characterized by the presence of castes, roles, and division of labor in the colony, including:

1. Queen, the fertile female ant whose job is to produce offspring during her lifetime. The queen is larger than the other ants in the colony. The queen has wings after the pupal phase and these wings can be removed after being fertilized by a drone (male);
2. Drone, the fertile male ants. The males have wings and play a role in fertilizing the queen. Drones will die shortly after fertilizing the queen;
3. Workers, the sterile female ants. Workers are responsible for finding food, caring for the queen, larvae, and maintaining the nest. In some species, worker ants have more specific roles. Minor worker ants are small in size and play a role in finding food, caring for larvae, and cleaning the nest. Major worker ants, which are large in size, play a role in expanding the nest, catching prey, and guarding the nest; and
4. Brood (eggs, larvae, pupae), the ants that cannot yet play a role in the colony and still need care from the queen and workers.

Ant colonies have a hierarchical structure, with a queen at the top and workers occupying different positions based on age and specialization. When a colony reaches a certain size or the right conditions, it can produce new queens and male ants to migrate and mate. When the females are fertilized, they will fly to a suitable place to form a new colony and continue the ant life cycle (Holman et al., 2010).

2.1.6. Ant Ecology

Ants have various roles in the ecosystem. Ants play a role in plant reproduction as seed dispersers because ants collect seeds to the nest, eat the outer layer of seeds, remove the remaining seeds, and cause seed germination from the remaining seeds that are discarded (Lengyel et al., 2009). Ants play a role in the nutrient cycle by collecting organic compounds such as dead insects and plant fragments which are then decomposed by microorganisms, enriching the soil with nutrients. Although ants are not primary pollinators like butterflies or bees, some species play a role in pollinating certain plants when worker ants search for nectar in flowers (Lengyel et al., 2014).

Ants that nest in the soil act as ecosystem engineers because they carry and move the availability of resources and change the soil environment. This behavior helps improve soil aeration, increases nitrogen, phospor, and potassium elements in the soil, and allows air and water to penetrate more easily so that soil fertility increases and helps increase plant growth (Brener and Werenkraut, 2017; Lima et al., 2022). Ant nests in the soil can help stabilize the soil and reduce erosion in some ecosystems during heavy rain (Li et al., 2019).

Ants can act as indicators of environmental change and ecosystem fertility. Changes in ant populations or the composition of ant species in an ecosystem can provide information about ecosystem dynamics. The presence of ants as colonial animals can affect the distribution and abundance of other organisms in the ecosystem, making them suitable candidates for biological control (Forbes and Northfield, 2017).

2.2. Environmental Factors that Affecting the Existence of Ants

2.2.1. Biotic Factors

a. Interspecific Interaction

The existence of ants is influenced by relationships with other organisms. The population of an ant colony is controlled by predators including spiders, birds, and insectivores. The presence of organisms that are beneficial to ants such as vegetation and leaf macrofauna causes symbiosis and improves the life of the ant colony. Ants compete between species and with other arthropods in obtaining food and territory (Palmer et al., 2010).

b. Intraspecific Interaction

Social insects such as ants are very sensitive to the presence and behavior of other individuals in their colony. Interactions between colony members, including aggression, cooperation, and division of labor, can impact the existence and success of the colony (Joseph, 2017).

2.2.2. Abiotic Factors

a. Temperature

The ideal temperature for ants to grow and develop ranges from 20 – 30^{o}C with a minimum tolerance temperature for survival of 10^{o}C and a maximum of 34^{o}C (Diamond *et al*., 2013). Extreme temperatures for ants can limit colony activity and development (Parr and Bishop, 2022).

b. Humidity

Humidity levels affect ant distribution. While some ant species can adapt to dry conditions, others require stable humidity levels to survive. Low humidity limits the foraging activity of ants and high humidity inhibits the ability of ants to maintain the nest (Elahi, 2005).

c. Rainfall

According to Heller et al. (2008) the distribution of ants increases in high rainfall and decreases in low rainfall. Drought conditions can limit the availability of food and water resources, thus affecting ant populations.

d. Soil pH

Most types of ants live and nest in soil with neutral pH. Soil pH can affect the type of vegetation present, and vegetation diversity affects food preferences and foraging patterns of ants (Agrawal et al., 2015).

e. Light Intensity

Light intensity and photoperiod (day length) can affect ant activity patterns and foraging behavior. Ants often avoid direct sunlight and choose shaded areas to avoid dehydration (Stukalyuk and Maák, 2023).

f. Abiotic Disturbances

Abiotic disturbances that affect the existence of ants include natural phenomena such as floods, fires, erosion, and changes in soil quality, both naturally and through human intervention (anthropogenic) (Latumahina et al., 2015).

2.3. Batutegi Protected Forest, Tanggamus

Based on the Decree of the Minister of Environment and Forestry Number: SK.68/Menhut-II/2010 dated January 28, 2010, Batutegi Protected Forest is a protected forest located in Tanggamus, Lampung with an area of 58,174 hectares. Astronomically, Batutegi Protected Forest is located at 104°27’ - 104°54’ East Longitude and 5°5’ - 5°22’ South Latitude. Geographically, Batutegi Protected Forest is located in Tanggamus Regency, West Lampung Regency, Pringsewu Regency, and Central Lampung Regency. The Batutegi Protected Forest area covers part of the area in Register 22 of Way Waya Protected Forest, Register 39 of North Kota Agung Protected Forest, and Register 32 of Bukit Ridingan Protected Forest.

Batutegi Protected Forest is divided into two zones, core zone and agroforestry (utilization) zone. Core zone, covering an area of 10,827 hectares, serves as a water source protection area. Meanwhile, the agroforestry zone has an area of 47,334.46 hectares, consisting of an area with a permit of 11,103.65 hectares and a specific area of 36,230.81 hectares. The function of each zone is adjusted to the laws and regulations governing the utilization of protected forests, with the aim of making it a limited utilization planning area. The division of zones in Batutegi Protected Forest aims to improve the efficiency of forest management (Ruchyansyah, 2014).

Batutegi Protected Forest Management is divided into six resort areas: Datar Setuju Resort, Ulu Semong, Banjaran, Batulima, Way Waya, and Way Sekampung (Figure 3) (Ruchyansyah, 2014). Way Sekampung Resort is part of the core zone and is surrounded by the Way Rilau River. This area has an ecosystem with various types of plants that act as resources for wildlife. This condition makes this area very suitable for research because it has natural resources that can be utilized by various wildlife (Ruchyansyah, 2014).

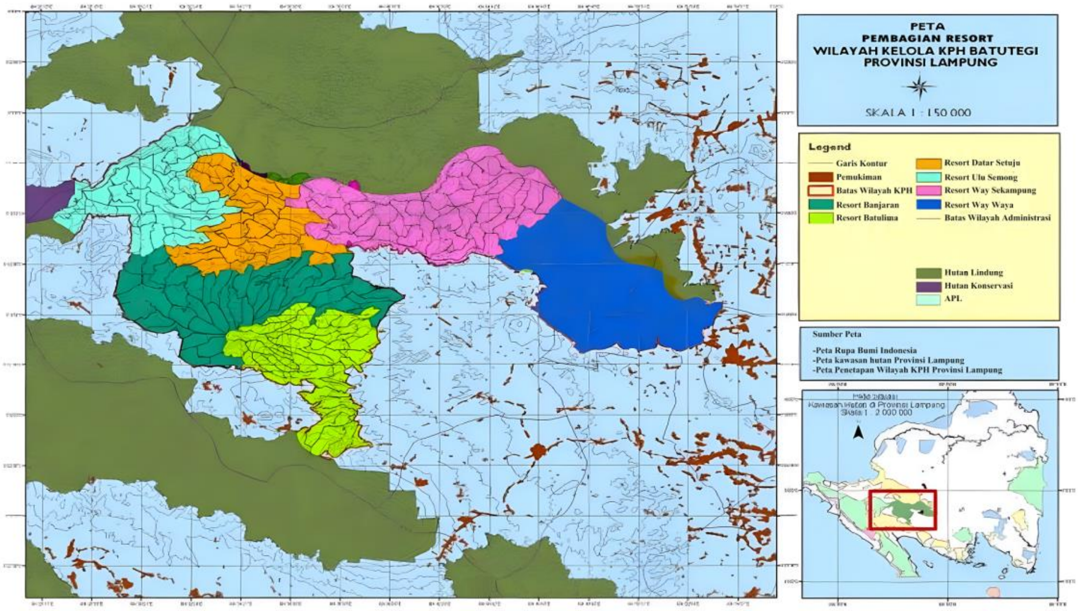

Figure 3. Map of Batutegi Protected Forest Resorts (Ruchyansyah, 2014).

The average annual rainfall in Batutegi Protected Forest is 2,378.8 mm, with the lowest value recorded in August at 83.4 mm, and the highest in December at 320.6 mm. The climate of this protected forest is included in the tropical rainforest climate category, with the lowest temperature above 18°C. Batutegi Protected Forest is included in the C2 agroclimate zone because it has a rainy season that lasts for six consecutive months and a dry season that lasts for two months (Ruchyansyah, 2014).

III. RESEARCH METHODOLOGY

3.1. Time and Place of Research

This research was conducted in January to February 2024 at the Way Rilau Research Station and farms that managed by GAPOKTAN Wana Tani Lestari, Batutegi Protected Forest, under Yayasan Inisiasi Alam Rehabilitasi Indonesia (YIARI) program, assisted by Heri Pranata, Hendra Saputra, and Cipto (YIARI staff). Ant identification was conducted at the Zoology Laboratory, University of Lampung.

3.2. Equipments and Materials

This study used pitfall traps to trap ants, sieves and tweezers for ant collection, plastic bottles to store specimens, fish-eye lenses to measure the percentage of canopy cover, 3 in 1 soil meters to measure temperature, pH, and soil moisture, 2 in 1 digital thermometers to measure temperature and air humidity, identification books ("Wajah-wajah Semut Eksotis di HPPB" by Herwina et al. (2018), "A Guide to the Ants of Jambi (Sumatra, Indonesia)" by Nazarreta et al. (2021), and "Introduction to The Study of Insects 7th Edition" by Borror et al. (2005)), and *Oppo Reno 8* smartphone for specimen documentation and to find out coordinates via the available GPS. The materials used included water, sugar, liquid detergent, 70% alcohol, ants and other macrofauna trapped in the pitfall trap.

3.3. Research Methods

3.3.1. Research Location and Procedure

This study was conducted on six types of habitats divided into two management zones in the Batutegi Protected Forest, the core zone (forest canopy, bushes, and riverside at the Way Rilau Research Station) and the agroforestry zone (dense farm, sparse farm, and irrigation side at the GAPOKTAN Wana Tani Lestari farm). Riverside are land that is close to the river flow, bushes are land that is only overgrown with weeds and shrubs, forest canopy are land that is overgrown with tree strata with dense canopy cover, dense farm are plantation areas with dense distances between plants, sparse farm are plantation areas with wide distances between plants, and irrigation side are areas on the edge of artificial water flows to irrigate plantation crops. The division of areas into various types of habitats is expected to show differences in ant types between types of habitats (Saefullah et al., 2015).

For each type of habitat, a transect line was determined purposively with a length of 100 meters, then a pitfall trap plot was made measuring 20 x 20 meters at both ends and in the middle of the transect, and 10 hand-collecting plots were made measuring 1 x 1 meter every 10 meters on the right and left sides of the transect alternately (Figure 4) (Adonovan et al., 2016; Gesriantuti et al., 2016).

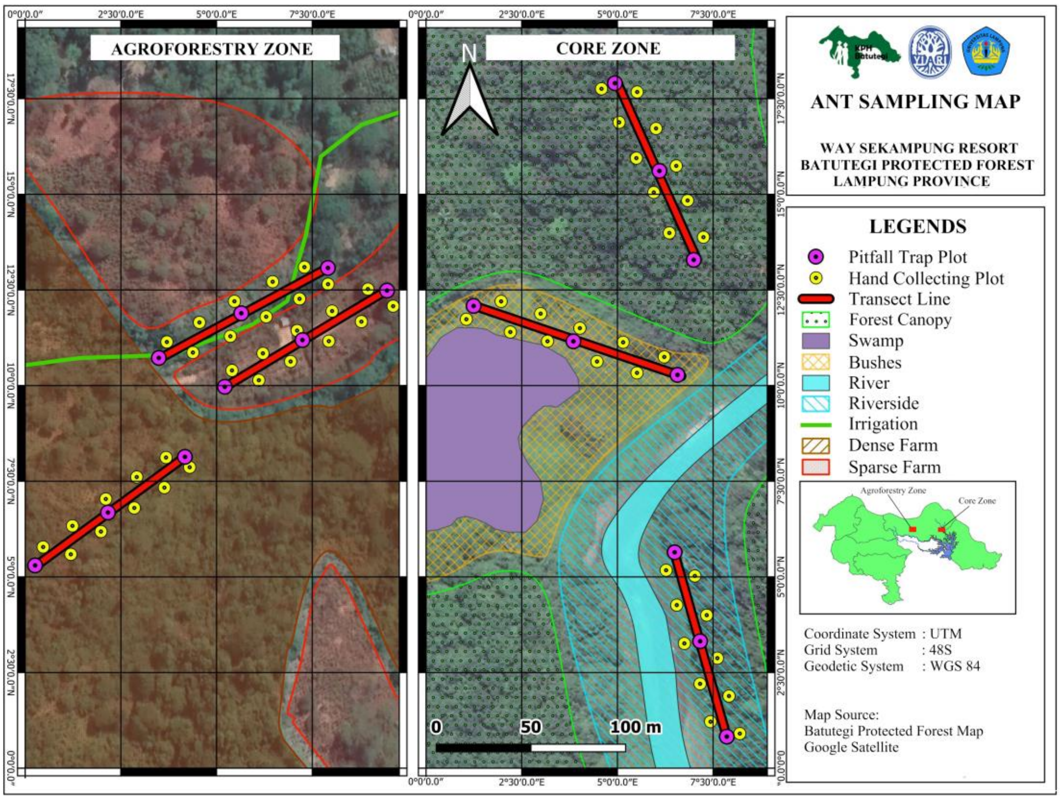

Figure 4. Ant sampling plot map at Way Sekampung Resort, Batutegi Protected Forest.

3.3.2. Sampling Methods

Ant sampling was carried out using three methods: epigaeic pitfall traps to trap ants on the ground surface, arboreal pitfall traps to trap ants on trees, and hand-collecting to catch ant directly. In each plot, three epigaeic pitfall traps were installed with a depth of 15 cm (Sheikh et al., 2018) and three arboreal pitfall traps at a height of 150 cm from the ground surface with trap models referring to Lasmar (2023) and Matevski et al. (2020) (Figure 5). The fixative solution used in each pitfall trap was a mixture of 200 ml of 35% alcohol; 2 ml of liquid detergent; and 2 tablespoons of granulated sugar (Sheikh et al., 2018; Achury et al., 2023). The traps were installed at 16.00 - 18.00 WIB with a distance of 5 meters for each trap (Figure 6). Arboreal pitfall traps were installed on trees with a height of more than 150 cm purposively. Specimens were taken 24 hours after installation (Schmidt and Solar, 2010) at 06.00 and 18.00 WIB with two repetitions (Agus and Septianjaya, 2021).

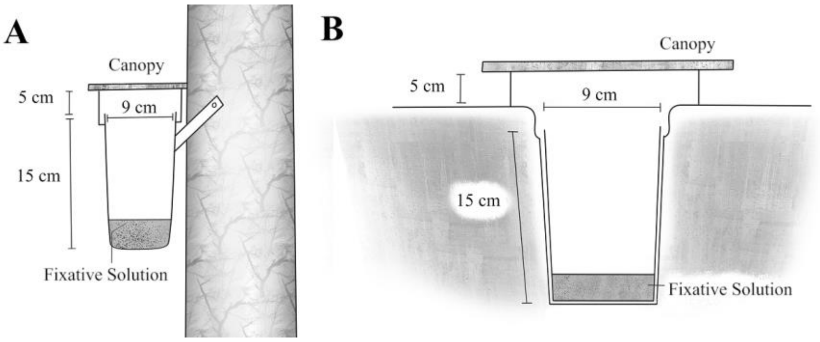

Figure 5. Arboreal Pitfall Trap (A) and Epigaeic Pitfall Trap (B).

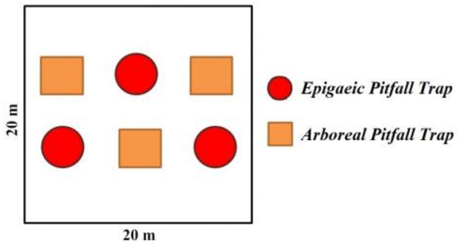

Figure 6. Pitfall trap placement pattern on plots at Way Sekampung Resort, Batutegi Protected Forest.

The hand-collecting method is carried out by catching ants and other macrofauna directly using tweezers. This method is carried out during the day (11.00 - 12.00 WIB) in each type of habitat with a time allocation of 6 minutes in each plot (Ahmad et al., 2019). A series of sampling procedures were carried out twice at the same location and plot.

3.3.3. Specimen Preservation

Preservation was carried out by placing ants and other trapped macrofauna in collection bottles containing 70% alcohol which were categorized based on the plot and sampling method with the label "A" for arboreal pitfall traps, "E" for epigaeic pitfall traps, and "HC" for hand-collecting.

3.3.4. Ant Identification

Ants were identified to species taxa. Identification was carried out by photographing the specimen clearly from the side and matching the morphology of the specimen with reference identification books (Herwina et al., 2018; Nazarreta et al., 2021), scientific articles, and antwiki.

3.3.5. Ecological Indices Measurements

The ant data obtained was tabulated using Microsoft Excel 2010. According to Magurran (2004) the ecological index is a measurement of the biodiversity of a community of living things in an ecosystem. The ecological indices used in the tabulation include the following.

a. Shannon-Wiener Diversity Index (H')

The Shannon-Wiener diversity index can be computed using a formula according to Magurran (1988).

$$H' = -\sum_{i=1}^{s} [p_i \ln p_i]$$

H' = Shannon-Wiener diversity index
p_i = ni/N
ni = number of individuals of each ant species
N = total individual of all ant species

The Shannon-Wiener diversity index is divided into three criteria, low if $H' \leq 1$, moderate if $1 < H' < 3$, and high if $H' \geq 3$ (Sidomukti and Wardhana, 2021).

b. Relative Abundance Index (RAI)

The relative abundance index can be computed using a formula according to Krebs (1989).

$$\text{RAI} = \frac{\text{ni}}{\text{N}} \times 100\%$$

RAI = relative abundance index
ni = number of individuals of each ant species
N = total individual of all ant species

A species is categorized as a dominant taxa if RAI ≥ 5%; sub-dominant if 2% < RAI < 5%; and non-dominant if RAI ≤ 2% (Elisabeth et al., 2021).

c. Simpson's Dominance Index (D)

The Simpson's dominance index can be computed using a formula according to Magurran (1988).

$$\text{D} = \sum \text{P}_i^2$$

D = Simpson's dominance index
p_i = proportion of individuals in species i

Species dominance is classified as low if D < 0.5; medium if 0.5 < D ≤ 0.75; and high if 0.75 < D ≤ 1 (Odum, 1993).

d. Margalef's Species Richness Index (R)

The Margalef's index can be computed using a formula according to Magurran (1988).

$$\text{R} = \frac{\text{S} - 1}{\ln \text{N}}$$

R = Margalef's species richness index
S = number of ant species
N = total individual of all ant species

Species richness is classified as low if the R value < 3.5; moderate if 3.5 < R < 5; and high if R > 5 (Magurran, 1988).

e. Jaccard Similarity Index (SJ)

The Jaccard similarity index can be computed using a formula according to Magurran (1988).

$$SJ = \frac{j}{(a + b - j)}$$

SJ = Jaccard similarity index
a = number of species found in habitat A
b = number of species found in habitat B
j = number of species found in both habitats

The maximum SJ value is 1. If the SJ value is closer to 1, then the similarity of ant types between one habitat and another is relatively high (Magurran, 1988).

f. Pielou's Evenness Index (E)

The Pielou's evenness index can be computed using a formula according to Magurran (1988).

$$E = \frac{H'}{\ln S}$$

E = Pielou's evenness index
H' = Shannon-Wiener diversity index
S = number of ant species

The ant community is classified as stable if the value is $0.75 < E \leq 1$; classified as unstable if the value is $0.5 < E \leq 0.75$; and classified as depressed if the value $0 < E \leq 0.5$ (Adelina et al., 2016).

3.3.6. Analysis of Biotic Factors in Ant Habitat

Biotic factors in ant habitats are determined by analyzing the association of ants with other macrofauna trapped in pitfall traps in several stages, as follows:

a. Arrangement of Family Pairs using 2x2 Contingency Table

Ant (Formicidae) was paired with other macrofauna families using a 2x2 contingency table (Table 1) based on Ludwig and Reynolds (1988) as follows.

Table 1. 2x2 contingency table

		Family A		
		Present	Absent	Total
Family B	Present	a	b	a+b=m
	Absent	c	d	c+d=n
	Total	a+c=r	b+d=s	N = a+b+c+d

a = Number of observation plots containing A and B families
b = Number of observation plots containing Family B
c = Number of observation plots containing Family A
d = Number of observation plots that Family A and B were absent

b. Statistical Analysis using Chi-Square Test

Determination of the presence or absence of association is done using the chi-square test by comparing the calculated x^2 value with the x^2 table in the chi square table with a significance level of 0.05 and a degree of freedom value of 1, so that the chi-square value is 3.841. If the calculated $x^2 > x^2$ table then there is an association, and if the calculated $x^2 < x^2$ table then there is no association. The formula for determining the calculated x^2 according to Ludwig and Reynolds (1988) is as follows.

$$\text{calculated } x^2 = \frac{N(ad - bc)^2}{m \cdot r \cdot n \cdot s}$$

c. Determining the Level of Association using the Ochiai Index (IO)

The Ochiai index can be computed using a formula according to Ludwig and Reynolds (1988).

$$IO = \frac{a}{\sqrt{a+b}\ \sqrt{a+c}}$$

IO = Ochiai index
a = Family A and B were present
b = Family A present, Family B absent
c = Family A absent, Family B present

The maximum value of the Ochiai index is 1. The association is very low if IO < 0.22; moderate if 0.23 < IO ≤ 0.48; high if 0.49 < IO ≤ 0.74; and very high if the index value is 0.75 – 1 (Indriyanto, 2006).

3.3.7. Analysis of Abiotic Factors in Ant Habitat

Abiotic factors that affect the presence of ants are air temperature, soil temperature, soil moisture, air humidity, and soil pH (Putra et al., 2017). Data on the percentage of canopy cover were taken using the Smartphone Hemispherical Photography method with a Spherical densiometer grid by positioning the lens vertically at the center of the observation location, calculating the number of corners on the grid covered by the canopy and multiplying it by 1.04 (Beeles et al., 2022).

Abiotic factor analysis was carried out using the Pearson correlation analysis method to determine whether there is a significant relationship between two variables (Bone et al., 2023). The Pearson correlation coefficient on the variable is assumed to be between -1 and 1. If the coefficient is negative, the correlation between the two variables is negative and vice versa (Sari and Aunurohim, 2013). The variables used in this method are abiotic factors and ant ecological index and are processed in SPSS 26.

The interval scale of the correlation coefficient according to Sarwono (2011) is as follows.

0	= No correlation
0.01 – 0.25	= very weak correlation
0.26 – 0.50	= sufficient correlation
0.51 – 0.75	= strong correlation
0.76 – 0.99	= very strong correlation
1	= perfect correlation

3.4. Research Flowchart

The research flowchart can be seen in Figure 7.

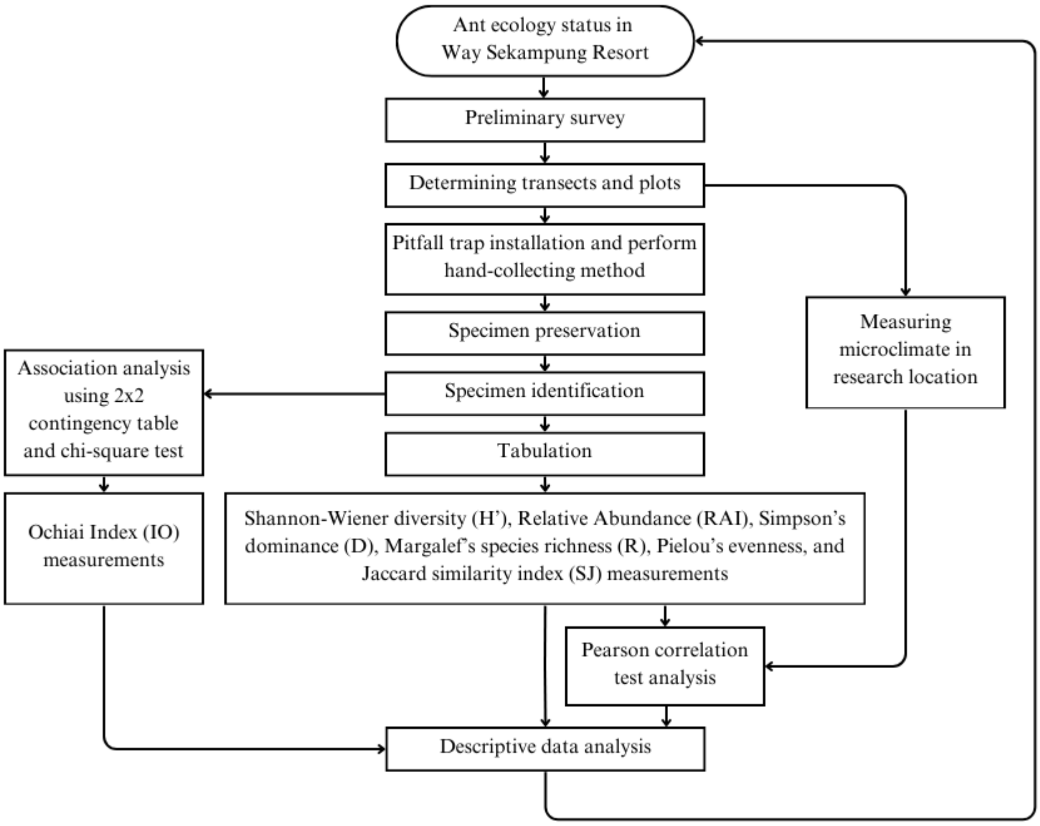

Figure 7. Flowchart of ant community structure research at Way Sekampung Resort, Batutegi Protected Forest.

V. CONCLUSION AND SUGGESTION

5.1. Conclusion

In conclusion, this study has several findings.

1. 1994 individuals from 84 ant species have been identified, with 691 individuals from 75 species found in the core zone and 1303 individuals from 25 species in the agroforestry (utilization) zone;
2. The diversity of ant species is classified as moderate (H’ = 2.963); the highest relative abundance in *A. gracilipes* with an RAI value of 32.29%; low species dominance (D = 0.127); high species richness (R = 10.92); unstable evenness (E = 0.67); and the similarity of ant species between habitat types is classified as low (SJ value ranging from 0.13 – 0.40);
3. Biotic factors that greatly influence the existence of ants in terms of association with other macrofauna that trapped in pitfall traps are the association between ants and Lycosidae as predators and Gryllidae as prey for ants. Abiotic factors that greatly influence the existence of ants are soil pH with a correlation value of 0.852 and soil moisture with a correlation value of 0.754.; and
4. The epigaeic pitfall trap method is efficient in obtaining the number of individual ants, and the arboreal pitfall trap is efficient in obtaining the number of ant species. Hand-collecting method is still needed to obtain ant species that are not caught in the pitfall trap..

5.2. Suggestion

More research is needed on the association between vegetation types and ant ecological indices at the research location to see if there is a significant relationship between plants and ant diversity. Research on the structure of ant communities using other sampling methods also needs to be done to enrich the data and find out if there are other ant species that can be obtained using methods other than pitfall traps and hand-collecting. The implication of this study is the need to maintain soil moisture from leaf litter to prevent a decrease in ant species diversity, and prevent of other cosmopolitan ant species that have the potential to harm the natural ecosystem.

BIBLIOGRAPHY

Abdullah, T., Aminah, S. N., Kuswinanti, T., Nurariaty, A., Gassa, A., Nasruddin, A., and F. Fatahuddin. 2020. The role of ants (Hymenoptera: Formicidae) in rice field. *IOP Conference Series: Earth and Environmental Science*. 486: 1-6. https://doi.org/10.1088/1755-1315/486/1/012167.

Achury, R., Staab, M., Bluthgen, N., and W. W. Weisser. 2023. Forest gaps increase true bug diversity by recruiting open land species. *Oecologia*. 202(2): 299 – 312. http://dx.doi.org/10.1007/s00442-023-05392-z.

Adelina, M., Harianto, S. P., dan N. Nurcahyani. 2016. Keanekaragaman Jenis Burung di Hutan Rakyat Pekon Kelungu Kecamatan Kotaagung Kabupaten Tanggamus. *Jurnal Sylva Lestari*. 4(2): 51-60. https://doi.org/10.23960/jsl2451-60.

Adonovan, S. T., Wulandari, D., dan R. Linda. 2016. Keanekaragaman Genus Dan Pola Distribusi Semut (Formicidae) pada Areal Perkebunan Jabon Putih (*Antocephalus cadamba* (Roxb.) Miq.) di Desa Durian Kabupaten Kubu Raya. *Jurnal Probiont*. 5(2): 53-58. https://dx.doi.org/10.26418/protobiont.v5i2.15938.

Agrawal, N., Minj, D. K., and B. K. Manker. 2015. Effect of pH and Moisture Content on Growth of Ant Colony at Different Vegetation Sites [Special issue]. *International Journal of Researches in Biosciences, Agriculture & Technology*. 2015(6): 79-81. https://ijrbat.in/upload_papers/270520171148441%20(23).pdf.

Agus, Y. H. dan T. Septianjaya. 2021. Semut (Hymenoptera: Formicidae) yang Ditemukan di Hutan Kota Bendosari, Kota Salatiga. *AGRIC: Jurnal Ilmu Pertanian*. 33(2): 215-224. http://dx.doi.org/10.24246/agric.2021.v33.i2.p215-224.

Ahmad, F., Putra, A. H., dan R. Y. Viza. 2019. Keanekaragaman Jenis Semut (Hymenoptera: Formicidae) di Hutan Adat Guguk Kabupaten Mrangin Provinsi Jambi. *BIOCOLONY: Jurnal Pendidikan Biologi dan Biosains*. 2(1): 32-42.

Ajerrar, A., Bouharroud, R., Zaafrani, M., Aabd, N. A., Qessaoui, R., Bahadou, H., Mayad, E. H., Tahiri, A., and B. Chebli. 2020. Ground foraging ants (Hymenoptera: Formicidae) in Argane (*Argania spinosa*, L) ecosystem: Response to grazing impact. *Asian Journal of Conservation Biology*. 9(1): 90-97. https://www.researchgate.net/publication/343362031.

Alfandy, D. D., Yulianty, Huda, R., Rustiati, E. L., Ruchyansyah, Y., dan H. Santoso. 2020. Keanekaragaman dan Potensi Tumbuhan di Blok Way Rilau, Resort Way Waya, Hutan Lindung Batutegi, Tanggamus, Lampung. *Prosiding*. 20 Juni 2020. Bandarlampung.

Andersen, A. N. 2018. Responses of ant communities to disturbance: Five principles for understanding the disturbance dynamics of a globally dominant faunal group. *Journal of Animal Ecology*. 88(3): 350-362. https://doi.org/10.1111/1365-2656.12907.

Beeles, K. L., Tourville, J. C., and M. Dovciak. 2022. Characterizing Canopy Openness Across Large Forested Landscapes Using Spherical Densiometer and Smartphone Hemispherical Photography. *Journal of Forestry*. 120(1): 37-50. http://dx.doi.org/10.1093/jofore/fvab046.

Borror, D. J., DeLong, D. M., Tripehorn, C. A., dan N. F. Johnson. 2005. *Introduction to the Study of Insects 7th Edition*. Thomson Brooks/Cole. Belmont.

Brassard, F., Leong, C. M., Chan, H. H., and B. Guénard. 2021. High Diversity in Urban Areas: How Comprehensive Sampling Reveals High Ant Species Richness within One of the Most Urbanized Regions of the World. *Diversity*. 13(8): 358-547. https://doi.org/10.3390/d13080358.

Brener, A. G. and V. Werenkraut. 2017. The effects of ant nests on soil fertility and plant performance: a meta-analysis. *Journal of Animal Ecology*. 86(4): 866-877. https://doi.org/10.1111/1365-2656.12672.

Bruhl, A. C., Mohamed, M., and K. E. Linsenmair. 1999. Altitudinal Distribution of Leaf Litter Ants along a Transect in Primary Forest on Mount Kinabalu, Sabah, Malaysia. *Journal of Tropical Ecology*. 15(3): 265-277. http://dx.doi.org/10.1017/S0266467499000802.

Collett, R. A. and D. O. Fisher. 2017. Time-lapse camera trapping as an alternative to pitfall trapping for estimating activity of leaf litter arthropods. *Ecology and Evolution*. 7(18): 7527-7533. https://doi.org/10.1002/ece3.3275.

Dejean, A., Corbara, B., Orivel, J., and M. Leponce. 2007. Rainforest Canopy Ants: The Implications of Territoriality and Predatory Behavior. *Functional Ecosystems and Communities*. 1(2): 105-120. https://www.researchgate.net/publication/285730052.

Diamond, S. E., Nichols, L. M., McCoy, N., Hirsch, C., Pelini, S. L., Sanders, N. J., Ellison, A. M., Gotelli, N. J., and R. R. Dunn. 2013. Using Physiology to Predict the Responses of Ants to Climatic Warming. *Integrative and Comparative Biology*. 53(6): 2305-2312. https:/doi.org/10.1093/icb/ict085.

Elahi, R. 2005. The effect of water on the ground nesting habits of the giant tropical ant, *Paraponera clavata*. *Journal of Insect Science*. 5(1): 34-40. http://dx.doi.org/10.1093/jis/5.1.34.

Elisabeth, D., Hidayat, J. W., dan U. Tarwotjo. 2021. Kelimpahan dan Keanekaragaman Serangga pada Sawah Organik dan Konvensional di Sekitar Rawa Pening. *Jurnal Akademika Biologi*. 10(1): 17-23. https://ejournal3.undip.ac.id/index.php/biologi/article/view/31061.

Endlein, T. and W. Federle. 2015. On Heels and Toes: How Ants Climb with Adhesive Pads and Tarsal Friction Hair Arrays. *PLoS ONE*. 10(11): 1-16. https://doi.org/10.1371/journal.pone.0141269.

Falibene, A., Rossler, W., and R. Josens. 2012. Serotonin depresses feeding behaviour in ants. *Journal of Insect Physiology*. 58(1): 7-17. http://dx.doi.org/10.1016/j.jinsphys.2011.08.015.

Fernández, F., Guerrero, R. J., and A. F. Sánchez-Restrepo. 2021. Systematics and diversity of Neotropical ants. *Revista Colombiana de Entomologia*. 47(1): 1-20. http://dx.doi.org/10.25100/socolen.v47i1.11082.

Forbes, S. J. and T. D. Northfield. 2017. Oecophylla smaragdina ants provide pest control in Australian cacao. *Biotropica*. 49(3): 328-336. http://dx.doi.org/10.1111/btp.12405.

Fujii, K., Toma, T., and Sukartiningsih. 2020. Comparison of soil acidification rates under different land uses in Indonesia. *Plant and Soil*. 465(10): 1-17. https://link.springer.com/article/10.1007/s11104-021-04923-y.

Gaytán, A., Bautista, J. L., Bonal, R., Moreno, G., dan G. G. Bornay. 2021. Trees Increase Ant Species Richness and Change Community Composition in Iberian Oak Savannahs. *Diversity*. 13(3): 115-126. https://doi.org/10.3390/d13030115.

Gesriantuti, N., Trantiati, R., dan Y. Badrun. 2016. Keanekaragaman Serangga Permukaan Tanah pada Lahan Gambut Bekas Kebakaran dan Hutan Lindung di Desa Kasang Padang, Kecamatan Bonaidarusalam, Kabupaten Rokan Hulu, Provinsi Riau. *Photon: Jurnal Sain dan Kesehatan*. 7(1): 147-155. https://doi.org/10.37859/jp.v7i01.569.

Gusmasri, R., Anwari, M. S., dan H. Prayogo. 2018. Keanekaragaman Jenis Semut (Formicidae) di Hutan Alam Sekunder Desa Sepandan Kecamatan

Batang Lupar Kabupaten Kapuas Hulu. *Jurnal Hutan Lestari*. 6(4): 1021-1027. https://dx.doi.org/10.26418/jhl.v6i4.30464.

Hanna, M. 2021. Thermoregulatory behaviours and ecology of wolf spiders in the Australian alpine region. *Field Studies in Ecology*. 3(1): 1-16. https://studentjournals.anu.edu.au/index.php/fse/article/view/267.

Heller, N. E., Sanders, N. J., Shors, J. W., and D. M. Gordon. 2008. Rainfall facilitates the spread, and time alters the impact, of the invasive Argentine ant. *Oecologia*.155(2): 385-395. http://dx.doi.org/10.1007/s00442-007-0911-z.

Herwina, H., Satira, R., dan Mairawita. 2018. *Wajah-wajah Semut Eksotis di Hutan Pendidikan dan Penelitian Biologi (HPPB)*. Rajawali Pers. Depok.

Holldobler, B. dan I. Wilson. 1990. *The Ants*. Harvard University Press. Cambridge Massachusetts.

Holman, L., Jorgensen, C. G., Nielsen, J., and P. d'Ettore. 2010. Identification of an ant queen pheromone regulating worker sterility. *Proceedings of the Royal Society B: Biological Sciences*. 277(1701): 3793-3800. http://dx.doi.org/10.1098/rspb.2010.0984.

Huda, R. 2022. *Burung Liar Kawasan Hutan KPH Batutegi, Lampung "Menyingkap Keragaman Burung di Hutan Lindung Batutegi"*. Yayasan IAR Indonesia. Bogor.

Indriyanto. 2006. *Ekologi Hutan*. Bumi Aksara. Jakarta.

Integrated Taxonomic Information System. 2023. "Formicidae". Diakses pada tanggal 12 September 2023 melalui https://itis.gov/servlet/SingleRpt/SingleRpt?search_topic=TSN&search_value=154193#null.

Isassi, J. I., Handa, I. T., Clavijo, A. A., Ramirez, S. E., Armbrecht, I., and J. P. Lessard. 2020. Shade-growing practices lessen the impact of coffee plantations on multiple dimensions of ant diversity. *Journal of Applied Ecology*. 58(5): 919-930. https://doi.org/10.1111/1365-2664.13842.

Ito, F., Makita, S., Nakao, H., Hosokawa, R., Kikuchi, T., and S. Yamane. 2021. Thelytokous parthenogenesis by dealate queens in the myrmicine ant Monomorium hiten distributed in Nansei Islands, western Japan, with description of the male. *Asian Myrmecology*. 14: 1-9. http://dx.doi.org/10.20362/am.012006.

Ješovnik, A. and J. Bujan. 2021. Wooded areas promote species richness in urban parks. *Urban Ecosystems*. 24:1305-1315. https://doi.org/10.1007/s11252-021-01112-8.

Joseph, S. 2017. The Behavioral Ecology and Intraspecific Interactions of Socially Parasitic Dulotic Ants. *Disertasi*. University of California. Santa Cruz.

Jurzenski, J., Albrecht, M., and W. W. Hoback. 2012. Distribution and diversity of ant genera from selected ecoregions across Nebraska. *The Prairie Naturalist*. 44(1): 17-29. https://digitalcommons.unl.edu/tpn/114/.

Kopecký, M., Macek, M., and J. Wild. 2021. Topographic Wetness Index calculation guidelines based on measured soil moisture and plant species composition. *The Science of The Total Environment*. 757: 1-19. http://dx.doi.org/10.1016/j.scitotenv.2020.143785.

Krebs, C. J. 1989. *Ecological Methodology*. Harper Collins Publisher. New York.

Laffitte, M. 2005. "Formic Acid (Methanoic Acid)". Diakses pada tanggal 12 September 2023 melalui https://www.chm.bris.ac.uk/motm/formic/ formich.htm.

Lapolla, J. S. and P. Barden. 2018. A new aneuretine ant from the Paleocene Paskapoo Formation of Canada. *Acta Paleontologica Polonica*. 63(3): 435-440. http://dx.doi.org/10.4202/app.00478.2018.

Lasmar, C. J. 2023. Assessing What Ants Eat and Where They Feed in Neotropical Biomes and Their Ecological Implications. *Bull Ecol Soc Am*. 104(2): 1-5. http://dx.doi.org/10.1002/bes2.2047.

Latumahina, F. 2015. Respon Semut Terhadap Kerusakan Antropogenik Pada Hutan Lindung Sirimau, Ambon. *Agrologia: Jurnal Ilmu Budidaya Tanaman*. 5(2): 53-66. http://dx.doi.org/10.30598/a.v5i2.188.

Lee, C. Y. and C. C. S. Yang. 2022. Biology, Ecology, and Management of the Invasive Longlegged Ant, *Anoplolepis gracilipes*. *Annual Review of Entomology*. 67: 43-63. https://doi.org/10.1146/annurev-ento-033121-102332.

Lee, R. H., Kwong, I. H. Y., Tsang, T. P. N., Wong, M. K. L., and B. Guénard. 2023. Remotely sensed environmental data as ecological proxies for ground-dwelling ant diversity along a subtropical forest succession gradient. *Journal of Ecology*. 111(7): 1428-1442. https://doi.org/10.1111/1365-2745.14109.

Lengyel, S., Gove, A. D., Latimer, A. M., Majer, J. D., and R. R. Dunn. 2009. Ant Sow the Seeds of Global Diversification in Plants. *PLoS ONE*. 4(5): 1-6. https://doi.org/10.1371/journal.pone.0005480.

.Lengyel, S., Gove, A. D., Latimer, A. M., Majer, J. D., and R. R. Dunn. 2010. Convergent evolution of seed dispersal by ants, and phylogeny and biogeography in flowering plants: A global survey. *Perspectives in Plant*

Ecology, Evolution and Systematics. 12(1): 43-55. http://dx.doi.org/10.1016/j.ppees.2009.08.001.

Li, T., Jia, Y., Shao, M., and N. Shen. 2019. *Camponotus japonicus* burrowing activities exacerbate soil erosion on bare slopes. *Geoderma*. 348: 158-167. https://doi.org/10.1016/j.geoderma.2019.04.035.

Lima, C., Helene, A. F., and A. Camacho. 2022. Leaf-cutting ants' critical and voluntary thermal limits show complex responses to size, heating rates, hydration level, and humidity. *Journal of Comparative Physiology B*. 192: 235-245. https://doi.org/10.1007/s00360-021-01413-6.

Ludwig, J. A. and J. F. Reynolds. 1988. *Statistical Ecology a Primer on Methods and Computing*. A Wiley-Interscience Publication. California.

Magurran, A. E. 1988. *Ecological Diversity and Its Measurement*. Croom Helm Ltd. London.

Magurran, A. E. 2004. *Measuring Biological Diversity*. Blackwell Science Ltd. Malden.

Matevski, D., Gjorgjievska, A. C., Prelic, D., Hristovski, S., Naumova, M., and C. Deltshev. 2020. Efficacy of trapping techniques (pitfall, ramp and arboreal traps) for capturing spiders. *Biologia*. 75(3): 2315-2319. https://doi.org/10.2478/s11756-020-00475-1.

Menzel, F., Zumbusch, M., and B. Feldmeyer. 2017. How ants acclimate: Impact of climatic conditions on the cuticular hydrocarbon profile. *Functional Ecology*. 32(3): 657-666. https://doi.org/10.1111/1365-2435.13008.

Mongkolsamrit, S., Kobmoo, N., Tasanathai, K., Khonsanit, A., Noisripoom, W., Srikitikulchai, P., Somnuk, R., and J. J. Luangsa-ard. 2012. Life cycle, host range and temporal variation of *Ophiocordyceps unilateralis*/*Hirsutella formicarum* on Formicine ants. *Journal of Invertebrate Pathology*. 111(3): 217-224. http://dx.doi.org/10.1016/j.jip.2012.08.007.

Murphy, S. M., Lewis, D., and G. M. Wimp. 2020. Predator population size structure alters consumption of prey from epigeic and grazing food webs. *Oecologia*. 192(3): 791-799. https://link.springer.com/article/10.1007/s00442-020-04619-7.

Nazarreta, R., Buchori, D., Hashimoto, Y., Hidayat, P., Scheu, S., and J. Drescher. 2021. *A Guide to the Ants of Jambi (Sumatra, Indonesia) Identification Key to Ant Genera and Images of the EFForTS collection*. LIPI Press. Jakarta.

Nie, L., Ni, M., Ning, D., Ran, H., Hassan, B., and Y. Xu. 2019. Comparing mechanisms of competition among introduced and resident ants in China: from behavior to trophic position (Hymenoptera: Formicidae). *Myrmecological News*. 29: 125-133. https://doi.org/10.25849/myrmecol.news_029:125.

Nie, L., Zhao, F., Chen, Y., Xiao, Q., Pan, Z., Ran, H., and Y. Xu. 2021. Prey Status Affects Paralysis Investment in the Ponerine Ant *Harpegnathos venator*. *Insects*. 13(1): 26-37. http://dx.doi.org/10.3390/insects13010026.

Odum, E. P. 1993. *Dasar-Dasar Ekologi*. UGM Press. Yogyakarta.

Ortega, M. R. and M. A. G. Martinez. 2018. Importance of Nesting Resources and Soil Conditions for the Recovery of Ant Diversity During Secondary Succession in a Tropical Rainforest. *Tropical Conservation Science*. 11(3): 1-14. http://dx.doi.org/10.1177/1940082918787063.

Palmer, T. M., Doak, D. F., Stanton, M. L., Bronstein, J. L., Kiers, E. T., Young, T. P., Goheen, J. R., and R. M. Pringle. 2010. Synergy of multiple partners, including freeloaders, increases host fitness in a multispecies mutualism. *Proceedings of the National Academy of Science*. 107(40): 17234-17239. http://dx.doi.org/10.1073/pnas.1006872107.

Parker, J. and D. J. C. Kronauer. 2021. How ants shape biodiversity. *Current Biology*. 31(19): 1141-1224. https://doi.org/10.1016/j.cub.2021.08.015.

Parr, C. L. and T. R. Bishop. 2022. The response of ants to climate change. *Global Change Biology*. 28(10): 3188-3205. https://doi.org/10.1111/gcb.16140.

Patel, D. and N. Bhatt. 2020. Nesting, Protective and Foraging Behavior of *Oecophylla smaragdina* (Weaver Ants) in Anand, Gujarat. *Advances in Zoology and Botany*. 8(4): 351-357. http://dx.doi.org/10.13189/azb.2020.080407.

Pinzon, J. and J. R. Spence. Performance of two arboreal pitfall trap designs in sampling cursorial spiders from tree trunks. *The Journal of Arachnology*. 36(2): 280-286. http://dx.doi.org/10.1636/CH07-97.1.

Prakash, J., Agrawal, S. B., and M. Agrawal. 2023. Global Trends of Acidity in Rainfall and Its Impact on Plants and Soil. *Journal of Soil Science and Plant Nutrition*. 23: 398-419. https://doi.org/10.1007/s42729-022-01051-z.

Putra, I. M., Hadi, M., dan R. Rahadian. 2017. Struktur Komunitas Semut (Hymenoptera: Formicidae) di Lahan Pertanian Organik dan Anorganik Desa Batur, Kecamatan Getasan, Kabupaten Semarang. *Bioma*. 19(2): 170-176. http://dx.doi.org/10.14710/bioma.19.2.170-176.

Rizal, Rifanjani, S., dan S. M. Kartikawati. 2020. Keanekaragaman Jenis Semut (Formicidae) di Kawasan Hutan Gunung Selindung Desa TWI Mentibar Kecamatan Selakau Kabupaten Sambas. *Jurnal Hutan Lestari*. 8(2): 278-285. https://dx.doi.org/10.26418/jhl.v8i2.39792.

Rizali, A., Karindah, S., Nugroho, C. T., and B. T. Rahardjo. 2021. Similarity of ant communities increases with isolation from natural habitat and abundance of invasive ants in oil palm plantations of Central Borneo. *Global Ecology and Conservation*. 28: 1-10. https://doi.org/10.1016/j.gecco.2021.e01690.

Ronque, M. U. V., Fourcassié, V., and P. S. Oliveira. 2018. Ecology and field biology of two dominant *Camponotus* ants (Hymenoptera: Formicidae) in the Brazilian savannah. *Journal of Natural History*. 52(3): 237-252. http://dx.doi.org/10.1080/00222933.2017.1420833.

Ruchyansyah, Y. 2014. *Rencana Pengelolaan Hutan Jangka Panjang Kesatuan Pengelolaan Hutan Lindung (RPHJP KPHL) Model Batutegi Provinsi Lampung Tahun 2014-2023*. Dinas Kehutanan Provinsi Lampung. Bandarlampung.

Saefullah, A., Mustari, A. H., dan A. Mardiastuti. 2015. Keanekaragaman Jenis Burung pada Berbagai Tipe Habitat Beserta Gangguannya di Hutan Penelitian Dramaga, Bogor, Jawa Barat. *Media Konservasi*. 20(2): 117-124. https://dx.doi.org/10.29243/medkon.20.2.%p.

Sari, L. N. dan Aunurohim. 2013. Korelasi Komunitas Nudibranchia dengan Komunitas Porifera di Perairan Pasir Putih, Situbondo. *Jurnal Sains dan Seni POMITS*. 2(2): 224-229. http://dx.doi.org/10.12962/j23373520.v2i2.4168.

Sarwono, J. 2011. *Analisis Statistika: Konsep dan Aplikasi dengan SPSS 20*. Salemba Empat. Jakarta.

Schmidt, F. A. and R. R. C. Solar. 2010. Hypogaeic pitfall traps: methodological advances and remarks to improve the sampling of a hidden ant fauna. *Insectes Sociaux*. 57(3): 261-266. http://dx.doi.org/10.1007/s00040-010-0078-1.

Schwarz, S., Albert, L., Wystrach, A., and K. Cheng. 2011. Ocelli contribute to the encoding of celestial compass information in the Australian desert ant *Melophorus bagoti*. *The Journal of Experimental Biology*. 214(6): 901-906. http://dx.doi.org/10.1242/jeb.049262.

Sidomukti, G. C. dan W. Wardhana. 2021. Penerapan Metode Storet dan Indeks Diversitas Fitoplankton Dari Shannon-Wiener Sebagai Indikator Kualitas Perairan Situ Rawa Kalong Depok, Jawa Barat. *Jurnal Teknologi*. 14(1): 28-38. https://doi.org/10.34151/jurtek.v14i1.3543.

Sheikh, A. H., Ganaie, G. A., Thomas, M., Bhandari, R., and Y. A. Rather. 2018. Ant pitfall trap sampling: An overview. *Journal of Entomological Research*. 42(3): 421-436. http://dx.doi.org/10.5958/0974-4576.2018.00072.5.

Smith, E. J., Vizueta, J., Younger, M. A., Mullen, S. P., and J. F. A. Traniello. 2023. Dietary diversity, sociality, and the evolution of ant gustation. *Frontiers in Ecology and Evolution*. 11: 1-9. https://doi.org/10.3389/fevo.2023.1175719.

Sommung, B. and T. J. Hawkeswood. 2017. Green Tree Ants, *Oecophylla smaragdina* (Fabricius, 1775) (Hymenoptera: Formicidae) killing and consuming a large cricket *Diaphanogryllacris* sp. (Orthoptera: Stenopelmatidae) near Ubon Ratchathani, Thailand. *Calodema*. 565: 1-3. https://www.researchgate.net/publication/318969876.

Sornapriya, J. and K. Varunprasath. 2018. Diversity of Ant Species (Hymenoptera: Formicidae) Nesting Beneath Different Trees in Periyanaickenpalyam, Coimbatore District, Tamil Nadu. *Advances in Research*. 17(6): 1-8. http://dx.doi.org/10.9734/AIR/2018/43338.

Sprenger, P. P., Musse, C., Hartke, J., Feldmeyer, B., Schmitt, T., Gebauer, G., and F. Menzel. 2021. Dinner with the roommates: trophic niche differentiation and competition in a mutualistic ant-ant association. *Ecological Entomology*. 46(3): 562-572.https://doi.org/10.1111/een.13002.

Steve, S. 2012. *Glossary Ant Myrmicine*. Australian National Insect Collection. Canberra.

Stark, A. Y., Arstingstall, K., and S. P. Yanoviak. 2018. Adhesive performance of tropical arboreal ants varies with substrate temperature. *Journal of Experimental Biology*. 221: 1-6. https://doi.org/10.1242/jeb.171843.

Stukalyuk, S., and I. E. Maák. 2023. The influence of illumination regimes on the structure of ant (Hymenoptera, Formicidae) community composition in urban habitats. *Insectes Sociaux*. 70(4): 1-15. http://dx.doi.org/10.1007/s00040-023-00935-2.

Taszakowski, A., Maslowski, A., Daane, K. M., and J. Brozek. 2023. Closer view of antennal sensory organs of two Leptoglossus species (Insecta, Hemimptera, Coreidae). *Scientific Reports*. 13(617): 1-16. http://dx.doi.org/10.1038/s41598-023-27837-4.

Tista, M. and K. Fiedler. 2011. How to evaluate and reduce sampling effort for ants. *Journal of Insect Conservation*. 15(4): 547-559. http://dx.doi.org/10.1007/s10841-010-9350-y.

Triyogo, A., Budiadi, Widyastuti, S. M., Subrata, S. A., dan S. S. Budi. 2020. Abundance of ants (Hymenoptera: Formicidae) and the functional groups in two different habitats. *Biodiversitas: Journal of Biological Diversity*. 21(5): 2079-2087. https://doi.org/10.13057/biodiv/d210535.

Uematsu, J., Hayashi, M., Shimoji, H., Salazar, M. O. L., and K. Tsuji. 2019. Context-dependent aggression toward non-nestmates in the ant *Diacamma* sp. from Japan. *Journal of Ethology*. 37(3): 259-264. http://dx.doi.org/10.1007/s10164-019-00611-8.

Verza, S. S., Mussury, R. M., Camargo, R. S., Andrade, A. P. P., and L. C. Forti. 2017. Oviposition, Life Cycle, and Longevity of the Leaf-Cutting Ant *Acromyrmex rugosus rugosus*. *Insects*. 8(80): 1-12. https://doi.org/10.3390/insects8030080.

Wang, C., Strazanac, J., and L. Butler. 2000. *Abundance, Diversity, and Activity of Ants (Hymenoptera: Formicidae) in Oak-dominated Mixed Appalachian Forest with Microbial Pesticides*. Smithsonian Institution Press. Washington.

Watanasit, S. dan T. O. Bickel. 2005. Diversity of Leaf Litter Ant Communities in Ton Nga Chang Wildlife Sanctuary and Nearby Rubber Plantations, Songkhla, Southern Thailand. *Songklanakarin Journal of Science and Technology*. 27(5): 943-955. https://www.researchgate.net/publication/26470632.

Wong, T. L. dan B. Guénard. 2021. Review of ants from the genus *Polyrhachis* Smith (Hymenoptera: Formicidae: Formicinae) in Hong Kong and Macau, with notes on their natural history. *Asian Myrmecology*. 13: 1-70. http://dx.doi.org/10.20362/am.013001

Yulminarti. 2021. Keanekaragaman dan Kepadatan Semut (Hymenoptera, Formicidae) di Lahan Gambut Alami. *BIOEDUSAINS: Jurnal Pendidikan Biologi dan Sains*. 4(2): 472-482. https://doi.org/10.31539/bioedusains.v4i2.2760.

Zhang, C. J., Cheng, Y. T., Luo, X. S., Chen, Y., He, Y. C., Li, Y. P., Huang, Z. P., Scott, M. B., and W. Xiao. 2023. Quantifying ant diversity and community in a subalpine forest mosaic: a comparison of two methods. *Journal of Insect Conservation*. 27(5): 813-824. http://dx.doi.org/10.1007/s10841-023-00501-y.

Zheng, Z., Hu, X., Xu, Y., Wei, C., and H. He. 2021. Bacterial Composition and Diversity of the Digestive Tract of *Odontomachus monticola* Emery and *Ectomomyrmex javanus* Mayr. *Insects*. 12(2): 176-190. https://doi.org/10.3390/insects12020176.