Diversity of Hymenopteran parasitoid in agricultural and primary forest in Lubuk Kilangan, Padang, West Sumatera, Indonesia

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Abstract. A hymenopteran parasitoid is an important natural enemy for many orders of insect pests. This group can control pests specifically in the agricultural ecosystem. The research aimed to study the diversity of hymenopteran parasitoids in the agricultural and primary forest ecosystems. A purposive random sampling method was used to determine the research location. Malaise and yellow trap were used to collect the samplings. The research location was agricultural and primary forest ecosystems. The result showed that families of the hymenopteran parasitoid in the dominant number of individuals and morphospecies were Braconidae, Ichneumonidae, and Scelionidae. According to the result, the diversity index in both ecosystems was high [4.879 for primary forest and 4.675 for agricultural]. The evenness index in both ecosystems was also high [0.905 for primary forest dan 0.887 for agricultural forest]. The similarity index in both ecosystems was classified as high [0.607 respectively].

1. Introduction

The ecosystem is a complex natural unity in composition and function [1]. The ecosystem without human intervention is called the natural ecosystem. For ecosystem with human intervention is called agroecosystems such as the rice field, plantation and artificial river. In the natural ecosystem, all organisms live in balance and control each other so that there is no pest outbreak. In the natural ecosystem, biodiversity is high which means in space unity, there was varied flora and fauna. Species diversity is a community characteristic that shows the level of organism diversity in the ecosystem. The low diversity occurs in the controlled ecosystem, characterized by a strong physical-chemistry limit factor [2].

Bung Hatta Natural Forest Park [BHNFK][Indonesian: Taman Hutan Raya Bung Hatta] is one of the natural ecosystems. This area is located in Indarung, Lubuk Kilangan, Padang, West Sumatera, Indonesia and managed by the Department of Agriculture of Padang. BHNFK is one of the primary forest nature reserves that play an important role as germplasm conservation, natural resources protection, education and research, natural love coaching and recreation. Geographically, the BHNFK is located in 100°17' - 100°42' East dan 0°32' - 1°5' South covered of ± 240 Ha [3].

Besides the natural ecosystem, agroecosystems are also found in Padang such as the rice field ecosystem. Rice field is an example of an agroecosystem that mainly produces rice [4]. As an ecosystem, the rice field consists of biotic and abiotic components forming biodiversity in this place.
In the natural ecosystem, herbivore insects are controlled by ecology [humidity and light intensity] and biotic [parasitization and predation]. In an agroecosystem, natural pest control does not run well due to the habitat quality decreases. The ecosystem can change to an agroecosystem and thus bring ecological processes and interaction between trophic levels that involve parasitoids, predator, herbivore, and host [5].

Agricultural cultivation has an impact on insect diversity. The insect diversity in a habitat is influenced by the environmental and vegetation that grows in this ecosystem. Insects causing damage and decreasing economic value of the crop is known as a pest. Currently, pest control is done by most farmers still use a synthetic pesticide that has many negative effects on the environment, plant and particularly human health. To solve this problem, an alternative way is required. One way that can be used is using biological control, a part of Integrated Pest Management [IPM] [6]. Biological control is a control that uses the biological agent for controlling the pest. One of the biological agents is parasitoid. As a biological agent, parasitoid is the best way to control pests than other ways.

A parasitoid is an insect group and most of them are from Hymenoptera order. A parasitoid is a pre-adult insect plays a role as a parasite in other insect bodies [host] so that the host dies, while the adult of parasitoid free lives in nature for looking for nectar and honeydew as food. Parasitoid consists of egg parasitoid, larvae parasitoid and pupae parasitoid [7]. According to LaSalle [8], parasitoid is a natural enemy in most pests and plays a role as key species in several ecosystems. Parasitoid can control specific pest and its population in nature is high [9]. The most parasitoid is monophagous, but several species are oligophagous [10].

Ecology conditions such as weather, temperature and host availability can influence parasitoid activity [11]. Parasitoid effectiveness depends on the ability to search and handle the host in a certain condition such as temperature, humidity, rainfall and number and host intensity of host [9]. The use of parasitoids for the long term can save maintenance costs such as pesticides and work so that the benefit increases. This research was aimed to study the diversity of Hymenoptera parasitoids in natural forest and agricultural ecosystems.

2. Materials and methods

2.1. Time and place
The research was conducted in the field and laboratory. The field experiment was conducted in a natural ecosystem, Bung Hatta Natural Forest Park [BHNFK][Indonesian: Taman Hutan Raya Bung Hatta] in Indarung, Lubuk Kilangan, Padang, while for agroecosystem study, conventional rice field in Batu Gadang, Lubuk Kilangan was chosen. The parasitoid identification was conducted in Bioecology Laboratory, Faculty of Agriculture, Andalas University, Padang, Indonesia. The research was carried out from March to June 2018.

2.2. Materials
The materials used in the research were a plastic bag, water, alcohol 96%, label, yellow fan trap, malaise trap, sampling bottle, scissor, binocular microscope, sieve, identification book, Hymenoptera of The World, stationery, Global Positioning System and camera.

2.3. Method
The survey method was used in the experiment, while sampling collection was conducted by a purposive random sampling method. The location was selected by the criteria, natural ecosystem [Bung Hatta Natural Forest Park] and agroecosystem [conventional rice field].

2.4. Hymenopteran parasitoid collection
The collection of the parasitoid was conducted for 2 months. Malaise and yellow fan trap was used for sampling collection. Sampling collection by using a yellow fan trap was conducted 2 times, in the
early and end of sampling collection, while sampling collection by using malaise trap was conducted every week.

Malaise trap looked like a tent. The trap consisted of 4 vertical nets that were stretched in each axis and formed angle 90°. In upper part was covered by 4 rectangular fabric that was adjusted. The collection tube was filled by 96% alcohol for 1/2 to 2/3 of tube volume. For the yellow fan trap, the diameter of the trap was 18 cm and 5 cm in height. The trap was filled by water on the surface with a little volume of detergent. Fifty yellow fan traps were laid randomly.

The identification of parasitoid was aimed to group and analyze parasitoid diversity. The identification book, Hymenoptera of the world was used for identifying the parasitoid [12].

2.5. Analysis of data

2.5.1. Richness and abundance of species

The parasitoid that found in the locations was calculated to determine the total of individual of family and morphospecies. Furthermore, the abundance and richness were determined according to the number of morphospecies found in the location.

a. Diversity index

Determining the diversity index of species was done by a formula described by Shannon-Wienner [13]:

\[ H' = - \sum_{i=1}^{s} P_i \log e P_i \]

Where: \( P_i = \frac{n_i}{N} \)

Note:

- \( H' \) = diversity index
- \( P_i \) = \( \frac{n_i}{N} \)
- \( n_i \) = number of species individual
- \( N \) = total of individual

| Value       | Note          |
|-------------|---------------|
| \( H' < 1.5 \) | Low diversity |
| \( 1.5 < H' < 3.5 \) | Moderate diversity |
| \( H' > 3.5 \) | High diversity |

b. Species evenness index

Species’ evenness index of the parasitoid was measured by using the Simpson formula, calculating the proportion of each species in a population in a certain place and time. Simpson evenness is determined using Krebs [14] formula:

\[ e = \frac{H}{Log S} \]

Note:

- \( e \) = Simpson evenness index
- \( S \) = Proportion of species in a community
The range of evenness value is 0-1 was determined as follows. If the value is close to 0, it indicates the insect distribution in an ecosystem is not well distributed. Otherwise, the value is close to 1, meaning that the distribution of insects is more evenly distributed [15].

**Table 2. Benchmark value of evenness index according to Krebs [14]**

| Value | Note         |
|-------|--------------|
| $E < 0.4$ | Low diversity |
| $0.4 < E < 0.6$ | Moderate diversity |
| $E > 0.6$ | High diversity |

c. Species similarity index
Species similarity index was aimed to study the proportion of species similarity between 2 communities. Species similarity index was measured using Jaccard species similarity [16]:

$$Is = \frac{2C}{A + B}$$

Note:
- $Is$ = species similarity index
- $A$ = number of species that found in community A
- $B$ = number of species that found in community B
- $C$ = number of similar species that found in both communities A and B

**Table 3. Benchmark value of species similarity index based on Barbour et al. [16]**

| Value | Note     |
|-------|----------|
| $Is < 0.25$ | Very low |
| $0.25 < Is < 0.5$ | Low    |
| $0.5 < Is < 0.75$ | High   |
| $0.75 < Is < 1$ | Very High |

d. Species accumulation value
The calculation of species accumulation value was aimed to study the increasing number of morphospecies found in each sampling location. The calculation was conducted using the EstimateS software.

3. Results and discussion

3.1. Number of individual and morphospecies of Hymenoptera in agricultural and primary forest ecosystem
According to the data in the agricultural ecosystem, in a total of 1,406 individuals and 62 morphospecies of non-parasitoid hymenopteran were found. For hymenopteran parasitoid, 2,262 individuals and 194 morphospecies were found. In the primary forest ecosystem, 1,195 individual and 55 morphospecies of non-parasitoid hymenopteran were found, while 1,684 individual and 219 morphospecies of hymenopteran parasitoid were found [Table 4.]
### Table 4. Number of hymenopterans and non-parasitoid hymenopterans in agriculture and primary forest

| Ecosystems    | Parasitoid | Non-Parasitoid |
|---------------|------------|----------------|
| A             |            |                |
| Agricultural  | 2,262      | 1,406          |
| Primary forest| 1,684      | 1,195          |
| B             |            |                |
| Agricultural  | 194        | 62             |
| Primary forest| 219        | 55             |

#### 3.2. Number of family, individual and morphospecies of hymenopteran parasitoid and non-parasitoid hymenopteran in agricultural and primary forest ecosystems

![Figure 1](image1.png)  
**Figure 1.** The number of Hymenopteran individual in agroecosystems. A. Agricultural and B. Primary forest

![Figure 2](image2.png)  
**Figure 2.** The number of Hymenopteran parasitoid morphospecies in agroecosystems. A. Agricultural and B. Primary forest
36 families in total were identified and 6 of them are not identified yet so far. Several families are not found in the agricultural ecosystem but they are found in primary forest i.e.: F, I and Leucospidae. On the other hand, several families are not found in the primary forest ecosystem, but they are found in the agricultural ecosystem i.e.: family B, D, and Aphelinidae. Most of the hymenopteran parasitoid individuals are found in the agricultural ecosystem, Scelionidae [528], Braconidae [319] dan Diapriidae [190] [Figure 2]. Most of the Hymenopteran parasitoid morphospecies were found in the agricultural ecosystem, Ichneumonidae [36], Braconidae [34] and Scelionidae [25]. In the primary forest ecosystem, the morphospecies is dominated by Braconidae [47], Ichneumonidae [34] and Scelionidae [26].

3.3. Number of morphospecies, abundance, evenness index and diversity of hymenopteran parasitoid in agricultural and primary forest ecosystem

The number of hymenopteran parasitoid morphospecies in a primary forest ecosystem is higher than the agricultural ecosystem, but in the agricultural ecosystem, individual abundance is higher than that in the primary forest. Species evenness index of the hymenopteran parasitoid in the primary forest is higher than in the agricultural ecosystem. The diversity index of a hymenopteran parasitoid of primary forest is higher than that in the agricultural ecosystem. This ecosystem is classified to have high evenness [0.905 for the agricultural ecosystem and 0.887 for the agricultural ecosystem] [Table 5].

Table 5. The number of morphospecies, abundance, evenness, and diversity of hymenopteran parasitoids in the primary and agricultural ecosystems.

| Parameter       | Agricultural | Primary forest |
|-----------------|--------------|----------------|
| Morphospecies   | 194          | 219            |
| Individual abundance | 2,262      | 1,684          |
| Evenness index  | 0.887        | 0.905          |
| Diversity index | 4.675        | 4.879          |

3.4. Similarity index of species of Hymenopteran parasitoid in agricultural and primary forest ecosystems.

Similarity level of hymenopteran parasitoid morphospecies in both ecosystems, agricultural and primary forest is classified to high with value 0.607 [Table 6].

Table 6. Similarity index species in agricultural and primary forest ecosystems

| Ecosystem     | Note | Primary forest |
|---------------|------|----------------|
| Agricultural  | -    | -              |
| Primary forest| 0.607| -              |

According to the data above, parasitoid and non-parasitoid of hymenopteran are found. Hymenoptera order is spread out entire agricultural vegetation, forest or other places that had a food source. Most number of individual and morphospecies of Hymenopteran that were collected from the locations is hymenopteran parasitoid [17]. Half of the parasitoid is from Hymenoptera that has a wide abundance and played an important role in the terrestrial ecosystem [9]. The tropical zone is a region that has the widest diversity of hymenopteran parasitoid species [18].

From 36 families of hymenopteran parasitoids that were found, Ichneumonidae and Braconidae are the largest numbers of morphospecies while Scelionidae and Braconidae are the largest number of individual. Ichneumonidae and Braconidae have spread out entire the world and survive in a varied
habitat from tropical, wet and dry zones [12]. Perdana [19] reported that Ichneumonidae and Braconidae are the dominant families in the forest ecosystem. In monoculture and polyculture vegetable agroecosystems, Ichneumonidae and Braconidae abundance is relatively high [20]. Yaherwandi et al. [21] stated that Braconidae, Ichneumonidae, and Scelionidae are dominant families in the agricultural ecosystem. Most of the species of these families play a role as a parasitoid of pest insect of Hemiptera such as brown plant hopper and Lepidoptera such as pod borer. Scelionidae abundance is higher in the opened ecosystem and obtained sunlight such as meadow habitat than forest [22]. Syafitri [23] reported that in Scirpophaga sp., several parasitoid species are found such as Telenomus rowani [Scelionidae] and Telenomus dignus [Scelionidae]. T. dignus is an egg parasitoid and these species are widely found in temperate and tropical zones. The adult of parasitoid lives in opened habitat and bright such as meadow [12].

In each ecosystem, some individual is different. The number of individuals in the agricultural ecosystem is higher than that in the primary forest ecosystem. This condition occurs due to the abundance of the plant plays a role as a food source affecting the parasitoid host. If the host is abundant, the parasitoid abundance is also high. Sperber et al. [24] reported that hymenopteran parasitoid interest to occupy an ecosystem is affected by a micro-habitat factor, food availability and parasitoid host availability. They are associated with a type of plant in an ecosystem. From this ecosystem, the largest number of hymenopteran parasitoid individuals is obtained in a malaise trap. This condition occurs due to the duration time of malaise in location was longer [8 hours] than the yellow fan trap [4 hours] and the size is larger. In the malaise trap, the largest number that is found is Scelionidae and Braconidae. In malaise, the largest morphospecies that is found are Ichneumonidae and Braconidae while in the yellow fan trap, the largest number is Braconidae and Scelionidae. Malaise trap and yellow fan trap are appropriate collection methods for Hymenoptera particularly parasitoid [25].

The number of morphospecies that found in both ecosystems always increases in each sampling. The increasing of number species is higher in the primary forest than that in the agricultural ecosystem. This condition due to vegetation in the agricultural ecosystem is relatively homogeneous so that the new morphospecies increasing is not significant. Otherwise, the vegetation of the primary forest ecosystem is more complex so that the increasing of hymenopteran parasitoid species occurs. Febrina et al. [26] stated that insect abundance in an ecosystem is affected by vegetation composition factors.

Index of hymenopteran parasitoid diversity is classified into high diversity [$> 3.5$]. The diversity index in a primary forest ecosystem is higher than that in the agricultural ecosystem. The comparison occurs due to the number of morphospecies that was obtained in the primary forest is higher than that in the agricultural ecosystem, while individual abundance is higher in the agricultural ecosystem than that in the primary forest ecosystem. Species' evenness index in these ecosystems is high. The value of abundance is $> 0.6$. Species of the primary forest ecosystem are more evenly distributed than in the agricultural ecosystem even though the evenness index is not significantly different. If the evenness index is close to 0, it means several species dominated the community, while if the value is close to 1, all species are at a similar evenness level [27].

The similarity index of the hymenopteran parasitoid is 0.607 and can be classified as high. This category shows that the species in a primary forest ecosystem is almost similar to the agricultural ecosystem. Hamid and Yunisman [20] stated that environmental conditions such as habitat diversity and landscape structure affect the diversity index, evenness, and similarity of an ecosystem [28].

4. Conclusion

The diversity index of these ecosystems is classified as high [4.879 for primary forest ecosystems and 4.675 for the agricultural ecosystem]. The evenness index of these ecosystems is classified as high [0.905 for primary forest ecosystem and 0.887 for the agricultural ecosystem]. The similarity index of species of both ecosystems is high [0.607].
References

[1] Baggethun EG, M Tudor, M Doroftei, S Covaliov, A Nastase, DF Onara, M Mierla, M Marinov, AC Dorosence, G Lupu, L Teodorof, IM Tudor, B Kohler, J Museth, E Aronsen, SI Johnsen, O Ibram, E Marin, and E Cioaca 2019 Change in ecosystem services from wetland loss and restoration: An ecosystem assessment of the Danube Delta (1960-2010) Ecosystem services. 39 100-965

[2] Oka IN 2005 Integrated Pest Management and implementation in Indonesia Yogyakarta-UGM Press.

[3] Fassandra F 2014 Management of Bung Hatta Natural Forest Park Padang, West Sumatera (Thesis) Padang State University

[4] Untung K 2006 The introduction of Integrated Pest Management (Second Edition) Gadjah Mada University Press-Yogyakarta

[5] Sahari B 2012 Structure of Hymenopteran parasitoid community in palm oil plantation, Pandu Senjaya, Pangkalan Lada, Central Kalimantan (Dissertation) Bogor Agricultural University-Bogor

[6] Habazar T and Yaherwandi 2006 Biological control of plant pests and disease Andalas University Press-Padang, Indonesia

[7] Purnomo H 2010 Introduction of biological control Gadjah Mada University Press-Yogyakarta

[8] LaSalle 1993 Parasitic Hymenoptera, Biological Control and Biodiversity: Hymenoptera and Biodiversity. Hymenoptera and Biodiversity (Wallingford: CAB International) pp. 197–215

[9] Godfray HJC 1994 Parasitoid: Behavioral and evolutionary ecology New Jersey-Princeton University Press

[10] Sunanro 2012 Biological control as integrated pest management Juniera 1 1-12

[11] Thompson LJ, S MacFadyen, and AA Hoffmann 2010 Predicting the effects of climate change on natural enemies of agricultural pests Biol Cont. 52 296-306

[12] Goulet H and JT Huber 1993 Hymenoptera of the world: An identification guide to families. Ottawa: Research branch agriculture Canada Publication

[13] Krebs CJ 1978 Ecology: The Experimental Analysis of Distribution and Abundance New York-Harper & Row Publisher

[14] Krebs CJ 2000 Ecological Methodology 2nd Edition New York-Benjamin Cummings

[15] Elkie PC, RS Remper, and AP Carr 1999 Patch Analyst User’s Manual: a Tool for Quantifying Landscape Structure Ontario-Thunder Bay Ontario Ministry of Natural Resources Boreal Science Northwest Science and Technology

[16] Barbour G, Burk J, and Pitts A 1987 Terrestrial Plant Ecology New York-The Benyamin/Cummings Publishing Company, Inc.

[17] Speight MR, MD Hunter, and AD Watt 2008 Ecofoly of Insect: Concepts and Applications 2nd Edition Oxford-Wiley Blackwell

[18] Stork NE 1991 The composition of the arthropods fauna of Bornean lowland rainforest trees J. Tropical Ecol.

[19] Perdana TAR 2010 Diversity of Hymenopteran insect in the rice field, vegetables, and forest in Bogor (Thesis) Bogor Agricultural University-Bogor

[20] Hamid H and Yunisman 2007 Hymenopteran parasitoid diversity in the various ecosystem in West Sumatera DP2M Dikti Report 1-14

[21] Yaherwandi 2009 Structure of the hymenopteran parasitoid community in several landscapes in West Sumatera Journal of Indonesian Entomology 6 1-14

[22] Masner L 1993 Superfamily Platygastroidea In: Goulet H and Huber JT (E-Communications Group)

[23] Syafitri Y 2017 Diversity of rice egg parasitoid of rice (Oryza sativa L.) in organic and conventional in Padang Pariaman (Thesis) Andalas University-Padang

[24] Sperber CF, K Nakayama, MJ Valarde, and FDS Neves 2004 Tree species richness and density affect parasitoid diversity in cacao agroforestry Basic Appl. Ecol. 5 241–251
[25] Atmowodi T 2000 Diversity of hymenopteran parasitoid diversity and anti-herbivore compound in Halimun National Park, West Java (Thesis) Bogor Agricultural University-Bogor

[26] Febrita E, Suwondo, and E Mayrita 2008 Structure of arthropods community in the soil of rubber plant \textit{(Hevea brasiliensis)} in Inuman, Kuantan Senggigi, Riau \textit{Pilar Science} \textbf{7} 37-45

[27] Magurran AE 1988 \textit{Ecological Diversity and Its Measurement} New Jersey-Princeton University

[28] Fauzan R 2018 \textit{Diversity of hymenopteran parasitoid in an agricultural and secondary forest ecosystem in the experimental garden, Faculty of Agriculture, Andalas University} (Thesis) Andalas University-Padang, Indonesia