



Ruth Stella Petrunella Thei <rstellapt@gmail.com>

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## [biodiv] Submission Acknowledgement

1 pesan

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**Ahmad Dwi Setyawan** <smujo.id@gmail.com>  
Balas Ke: Ahmad Dwi Setyawan <editors@smujo.id>  
Kepada: Ruth Stella Petrunella Thei <rstellapt@gmail.com>

9 September 2020 19.37

Ruth Stella Petrunella Thei:

Thank you for submitting the manuscript, "Arthropod dynamic diversity in the rice field ecosystem in Central Lombok" to Biodiversitas Journal of Biological Diversity. With the online journal management system that we are using, you will be able to track its progress through the editorial process by logging in to the journal web site:

Submission URL: <https://smujo.id/biodiv/authorDashboard/submission/6761>

Username: dr\_stella

If you have any questions, please contact me. Thank you for considering this journal as a venue for your work.

Ahmad Dwi Setyawan

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[Biodiversitas Journal of Biological Diversity](#)



Ruth Stella Petrunella Thei <rstellapt@gmail.com>

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## Request Revisions

1 pesan

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**Managing Editor** <unsjournals@gmail.com>

9 September 2020 21.17

Kepada: rstellapt@gmail.com

Cc: abadiabdullatief@gmail.com, gatotmudjiono@gmail.com, suprayogod@gmail.com

Ruth Thei, Abdul Abadi, Gatot Mudjiono, Didik Suprayogo:

We have reached a decision regarding your submission to Biodiversitas Journal of Biological Diversity, "Arthropod dynamic diversity in the rice field ecosystem in Central Lombok".

Our decision is: Revisions Required

Note: Kindly TURN ON track changes when revising it.

Smujo Editors

[editors@smujo.id](mailto:editors@smujo.id)

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Reviewer B:

This manuscript studied on arthropod dynamic diversity in the rice field ecosystem in Central Lombok during the rainy season. This paper can be published with revisions.

Many Latin names of species were written incorrectly. Some of them need justification.

Please add Supplementary Table 1.

Please check the references, some of the literatures were not cited.

I put my comments and suggestions in the text.

Recommendation: Revisions Required

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Thank you,

Regards,

**Ahmad Dwi Setyawan**

Managing Editor,



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1166K

## Response Letter

Title: Arthropod dynamic diversity in the rice field ecosystem in Central Lombok

No.	Comments	Responses
1	<p>In the Intro: There is a bunch of studies on arthropods in rice field ecosystems in indonesia. Even in the Biodiversitas Journal we can find several of them (e.g. Prabawati et al, 2019; Karenina et al, 2019; Herlinda et al 2020; etc). So, in the Intro I would suggest to review and elaborate those studies in one paragraph. Then, in a subsequent paragrahp the author(s) can highlight the uniqueness/importance of the study. For example, the study can enrich the existing knowledge on agroecosystem entomology in tropics, particularly in the context of study area (i.e. Lombok Island) which might differ with the previous studies.</p>	<p><b>Line 45-55 (Introduction)</b> We have revised this section. <b>Done</b></p>
2	<p>In the Methods: Please add map of study location (and inset map of Indonesia) as not all readers (e.g. non-Indonesians) are familiar with the region</p>	<p><b>Line 66-68 (Methods)</b> We have added map of study location. <b>Done</b></p>
3	<p>In the Results and Discussion: The parts that explaining Figures 1 and 2 are confusing since there are many inconsistencies between what presented in the figures, the figure captions, and in the text.</p> <p>For example, the caption of Figure 1 says the composition of species while the figure itself presenting ecological functions.</p> <p>Also, in the text said that there is 5 species and 3 families of Odonata, while Figure 2 suggests that there is only one species and family from this group.</p> <p>Please check again the consistency between the figure, figure caption and what explained in the text.</p>	<p><b>Figure 2 and 3</b> We have revised this part. <b>Done</b></p>

No.	Comments	Responses
4	<p><b>Land</b></p> <p>Do you mean this is in total?</p>	<p><b>Table 2</b></p> <p>We have revised this part</p> <p><b>Done</b></p>
5	<p><i>5-pustulatus</i></p> <p>Is this a correct way in naming the species?</p>	<p><b>Line 149-150</b></p> <p>We have corrected this scientific name.</p> <p><b>Done</b></p>
6	<p>The species the first week after plantation and more than 50 % of them were natural enemies of pest species.</p> <p>It is not clear what you want to say hear. Please edit the text to make it clearer.</p>	<p><b>Line 157-158</b></p> <p>We have revised this part.</p> <p><b>Done</b></p>
7	<p>Where is the Supplementary Table 1? I cannot find it in the document. Instead of put it as Supp. table, I would suggest to add the table as an appendix.</p>	<p><b>Line 193</b></p> <p>We have revised this part.</p> <p><b>Done</b></p>
8	<p>Figure 5: It is not directly clear what the figure tells about. I suggest to describe what pictorial role is about and how you did the analysis. Also, it is not clear what the numbers in the triangle refer to? Please add information/note about those numbers.</p>	<p><b>Line 186-189 and 195-196</b></p> <p>We have revised this part.</p> <p><b>Done</b></p>
10	<p>The conclusion is too short. I would suggest to make it into one paragraph with sufficient numbers of sentence.</p>	<p><b>Line 267-276</b></p> <p>We have revised this section.</p> <p><b>Done</b></p>

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**[biodiv] Editor Decision**

1 pesan

**Smujo Editors** <smujo.id@gmail.com>

16 September 2020 11.00

Balas Ke: Smujo Editors &lt;editors@smujo.id&gt;

Kepada: Ruth Stella Petrunella Thei &lt;rstellapt@gmail.com&gt;, Abdul Latief Abadi &lt;abadiabdullatief@gmail.com&gt;, Gatot Mudjiono &lt;gatotmudjiono@gmail.com&gt;, Didik Suprayogo &lt;suprayogod@gmail.com&gt;

Ruth Stella Petrunella Thei, Abdul Latief Abadi, Gatot Mudjiono, Didik Suprayogo:

We have reached a decision regarding your submission to Biodiversitas Journal of Biological Diversity, "Arthropod dynamic diversity in the rice field ecosystem in Central Lombok".

Our decision is: Revisions Required

Smujo Editors  
[editors@smujo.id](mailto:editors@smujo.id)

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Reviewer A:

Dear Editor,

Please find attached is the reviews and suggested edits for the manuscript "Arthropod dynamic diversity in the rice field ecosystem in Central Lombok".

This paper is written in very good English, so I enjoyed the reads. I also appreciate the extensive fieldwork conducted with a long period of data collection. While the findings of this study can enrich the existing knowledge in the field of agroecosystem entomology especially in the tropics, there are several things to clarify and improve the paper (as detailed in the attached document). In particular, things that became my concerns are:

1. In the Intro: There is a bunch of studies on arthropods in rice field ecosystems in indonesia. Even in the Biodiversitas Journal we can find several of them (e.g. Prabawati et al, 2019; Karenina et al, 2019; Herlinda et al 2020; etc). So, in the Intro I would suggest to review and elaborate those studies in one paragraph. Then, in a subsequent paragraph the author(s) can highlight the uniqueness/importance of the study. For example, the study can enrich the existing knowledge on agroecosystem entomology in tropics, particularly in the context of study area (i.e. Lombok Island) which might differ with the previous studies.
2. In the Methods: Please add map of study location (and inset map of Indonesia) as not all readers (e.g. non-Indonesians) are familiar with the region.
3. In the Results and Discussion: The parts that explaining Figures 1 and 2 are confusing since there are many inconsistencies between what presented in the figures, the figure captions, and in the text. For example, the caption of Figure 1 says the composition of species while the figure itself presenting ecological functions. Also, in the text said that there is 5 species and 3 families of Odonata, while Figure 2 suggests that there is only one species and family from this group. Please check again the consistency between the figure, figure caption and what explained in the text.
4. Where is the Supplementary Table 1? I can not find it in the document. Instead of put it as Supp. table , I would suggest to add the table as an appendix.
5. Figure 5: It is not directly clear what the figure tells about. I suggest to describe what pictorial role is about and how you did the analysis. Also, it is not clear what the numbers in the triangle refer to? Please add information/note about those numbers.

Best regards,

Reviewer

Recommendation: Revisions Required

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Biodiversitas Journal of Biological Diversity



**A-04-SEP-SGB-Arthropod dynamic diversity in the rice field ecosystem\_InternalRev.doc**  
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# The dynamics of Arthropod diversity and abundance in rice field ecosystem in Central Lombok, Indonesia

**Abstract.** Arthropods have roles as pests, decomposers, pollinators, and natural enemies of pests. Natural enemies play a vital role in pest population control by predation or parasitism. A study of the arthropod community in the rice field ecosystem was conducted in Central Lombok, Indonesia from December 2009 to March 2010 in order to elucidate the composition, structure, and dynamic diversity of arthropods present. Arthropod sampling was done by pitfall traps, yellow pan traps, and insect net. Arthropod dynamic diversity, especially of natural enemies, was determined by diversity index, dominance index, evenness analysis, and pictorial analysis. Based on taxonomical perspective, as many as 98 arthropod species were found, including 85 insect species from 59 families and 9 orders; and 13 spider species in 6 families. Based on the ecological functions, predator arthropods were the most common (33 species, dominated by spiders), but the phytophage arthropods had the most species richness (49.34 %). A high Shannon index (3.18) and Pilou index (0.7) indicated dominant arthropods in the ecosystem. Arthropod species richness and diversity increased alongside rice development and decreased after harvest.

**Key words:** Arthropods, diversity, rice field ecosystem, species richness

**Running title:** Arthropod diversity in rice field ecosystem

## INTRODUCTION

An agroecosystem, just like any other ecosystems, contains biotic and abiotic components that interact each other which affects the growth and development of the biotic components (Altieri 1995). One of the biotic components of an agroecosystem is arthropods, which have roles in the ecosystem as pests, decomposers, pollinators, and natural enemies of pests. As pest would lower agricultural production, natural enemies are an important part of the ecological process as they can control pest populations through parasitism or predation.

In rice field agroecosystem, natural predators of pests are various and abundant (Bambaradeniya 2000). For example, Laba (2001) stated that no less than 700 species of insects, including parasitoids and predators, were found in rice field ecosystems without any pest infestations, such as brown leafhoppers. Settle *et al.* (1996) documented 765 spider species in a rice field ecosystem with irrigation in Indonesia. Bambaradeniya and Amerasinghe (2008) noted that spiders comprised more than 50 % of arthropods in Sri Lankan rice fields. As many as 46 predators and 14 parasitoid species were found in rice fields in the Philippines (Heong *et al.* 1991). Those studies indicate that natural predators can adapt to continuously disturbed ecosystems such as in rice field. The high adaptability of natural predators makes them feasible to be used in annual crop agroecosystems.

Nowadays, as agroecosystems become modernized, high energy inputs are often involved, including the use of chemical fertilizers, pesticides, and other agricultural chemicals. The excessive uses of those chemicals are already shown to cause pervasive ecological results and imbalances in the ecosystem. Imbalances in ecosystem are caused by poorly managed environment without regard to any ecological principles (Altieri & Nicholls 2004). Altieri and Nicholls (2004) stated that ecosystem management and agricultural practice may affect the diversity of predators and pests. This suggests that the lack of ecological balance and sustainability may cause continuous pest attack, erosion, water pollution, and so on. The uses of agricultural cultivation technologies and agrochemical applications are often harmed the natural enemies of the pests, depleting the ecological services provided by the agroecosystem and eventually collapsing the environment.

Some previous studies on arthropods in rice field ecosystems in Indonesia have been reported (Prabawati *et al.* 2019; Karenina *et al.* 2019; Herlinda *et al.* 2020; Wakhid *et al.* 2020). Prabawati *et al.* (2019) reported that the abundance of

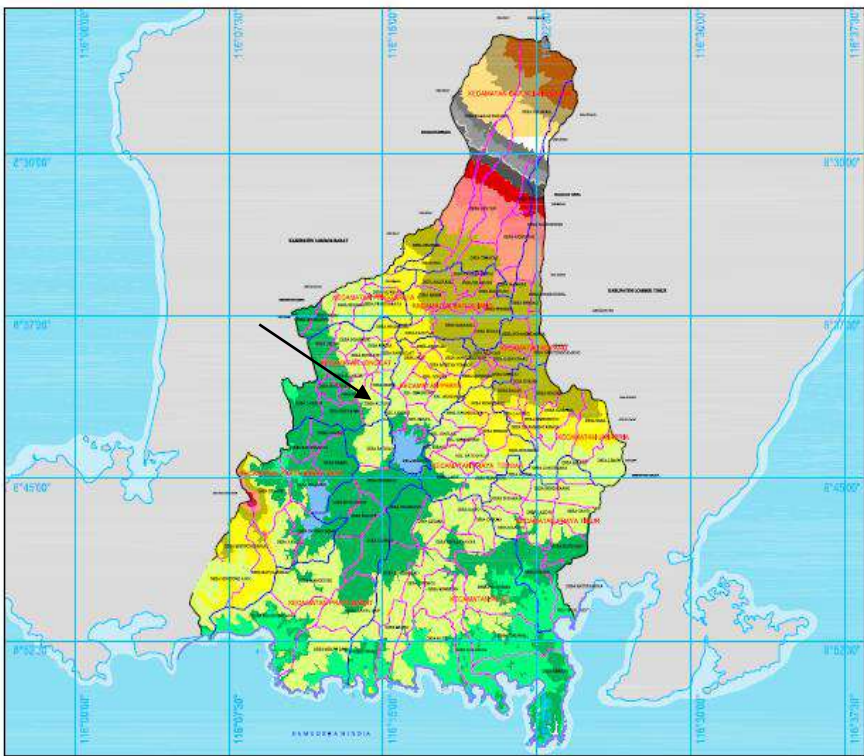
47 canopy arthropods in South Sumatra (Indonesia) freshwater swamp main and ratooned rice applied with bioinsecticides  
48 and synthetic insecticide. Karenina *et al.* (2019) showed that herbivore population and the lowest of spiders abundance in  
49 rice field ecosystems with synthetic insecticide application and significantly different with population in rice field  
50 ecosystems with refugia. The lowest of predatory insects abundance in plots with Abamectin applications reduced the  
51 parasitoid and herbivore number in freshwater swamps of South Sumatra, Indonesia (Herlinda *et al.* 2020). Furthermore,  
52 the aquatic insect community in rice field ecosystems also reported in Bogor, West Java, Indonesia (Wakhid *et al.* 2020).  
53 However, there is little information about arthropods diversity and abundance dynamics in rice field ecosystem in Central  
54 Lombok, West Nusa Tenggara Province, Indonesia. Our present study could enrich the existing knowledge on  
55 agroecosystem entomology in tropics, particularly in Lombok Island.

56 This study aimed to elucidate the diversity dynamic of arthropods in rice field ecosystems in Lombok Island and to  
57 reveal the community composition of pest and natural enemy arthropods in rice fields and the ecosystem surrounding  
58 them. We expected the results of this study can help the management of rice field ecosystems and the ecosystems  
59 surrounding them in hope to create greater sustainability.

## 60 MATERIALS AND METHODS

### 61 Study period and area

62 The study was conducted from December 2009 to March 2010. Arthropods were sampled in three acres of rice fields  
63 located in Puyung, Central Lombok District, West Nusa Tenggara Province, Indonesia (Figure 1). The seeding, planting,  
64 fertilization, and management of rice was based on local practices following the technical standards prescribed by  
65 company partner.



66 Figure 1 Map of Central Lombok District West Nusa Tenggara Province, Indonesia area showing location of sampling sites  
67 (marked with black arrow) (Source: Bappeda Central Lombok District)  
68

### 69 Sampling methods

70 Sampling was performed starting from two weeks after rice planting until one week after harvest with a 14-day  
71 sampling interval. Swing nets (20 double swings) were used to sample arthropods in the plant canopy while 60 yellow pan  
72 traps with 3 repetitions were placed at an equal distance between them throughout the sampling area. Ground surface  
73 arthropods were sampled by pitfall traps, with the same setting of the yellow pan trap (60 traps in total with 3 times  
74 repetition). All traps were set and collected after 24 hours. Every trapped arthropod was submerged in ethyl acetate,  
75 filtered out of the liquid with filter paper, rinsed with tap water, stored in 70 % alcohol solution, and transferred to the  
76 laboratory for identification. Kalshoven (1981), Lawrence and Britton (1994), and Hadlington and Johnston (1987)  
77 manuals were used for sample identification and species identifications were recorded. Sample identification was



78 performed at Mataram University and the Zoology Lab, Research Center for Biology, Indonesian Institute of Sciences  
 79 (LIPI), Cibinong.

80 **Data analysis**

81 Data were analyzed for: (1) diversity index (Eq. 1) (Rahayu *et al.* 2006); (2) dominance index (Eq. 2); (3) evenness  
 82 index (Eq. 3) (Ludwig and Reynolds 1988); and species similarity (Eq. 4) (Southwood 1980).

83 
$$H' = - \sum p_i \ln p_i$$
 (1)

84  $P_i$  = Proportion of species  $i$

85 
$$D = \frac{n_i}{N} \times 100\%$$
 (2)

86  $N_i$  = Total of Species  $I$ ,  $N$  = Total sampled individual

87 
$$E = H' / \ln(S)$$
 (3)

88  $H'$  = Diversity index,  $S$  = Species count

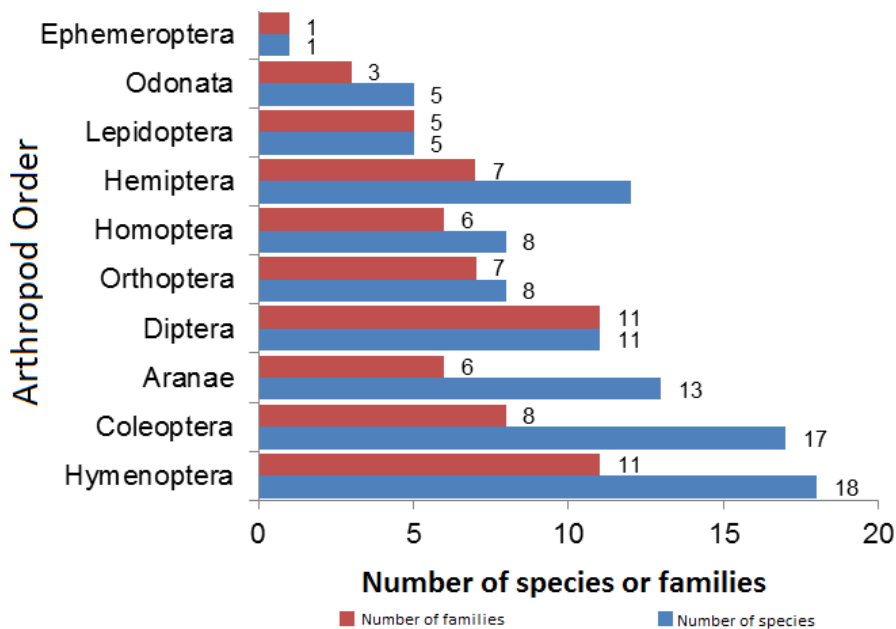
89 
$$Cs = 2j / (a + b)$$
 (4)

90  $a$  = Total species in habitat  $a$ ,  $b$  = Total species in habitat  $b$ ,  $j$  = Total of same species found in  $a$  and  $b$  habitat

91 **RESULTS AND DISCUSSION**

92 **Arthropods composition and richness based on taxonomy**

93 The Coleoptera (17 species from 8 families) was dominated by the Carabidae family (4 species) and Coccinellidae (3  
 94 species). Aranae was the third biggest arthropod group in the sample, consisting of 13 species in 6 families with Lycosidae  
 95 and Araneidae as the most sampled family. Twelve species from 7 families of Hemiptera and 11 species from 11 families  
 96 of Diptera were sampled during the study. Tetrigidae dominated in Orthoptera samples, with 8 species and 7 families.  
 97 Cicadellidae was the dominating family from Homoptera (8 species and 6 families). The sampling found 5 species and 5  
 98 family of Lepidoptera and 5 species and 3 families of Odonata. Baetidae was the only family of Ephemeroptera collected  
 99 during the sampling (Fig. 2).



100

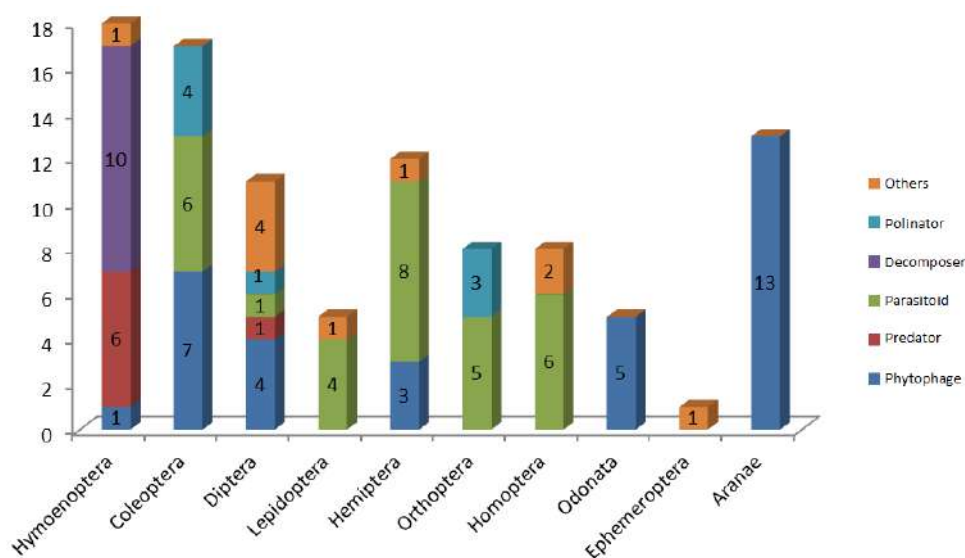
101 **Figure 2.** The composition of Arthropod species based on ecological functions in the land of rice in Central Lombok

102 **Arthropods composition and richness based on ecological function**

103 Based on their ecological function, all samples could be divided into 33 predator species, 7 parasitoid species, 30  
 104 phytophage species, 8 decomposers, 10 pollinators, and 10 arthropod species with other ecological functions (Fig. 3).  
 105 Based on ecological function, all obtained arthropods could be divided into 33 predator species (1 species of Hymenoptera,  
 106 7 species of Coleoptera, 4 species of Diptera, 3 species of Hemiptera, 5 species of Odonata, and 13 species of Aranae), 7

107 species of parasitoid (6 species of Hymenoptera and 1 species of Diptera), and 30 species of phytophage (6 species of  
 108 Coleoptera, 1 species of Diptera, 4 species of Lepidoptera, 8 species of Hemiptera, 5 species of Orthoptera, and 6 species  
 109 of Homoptera), 10 species of Hymenoptera of Pollinator, 8 species of decomposers (4 species of Coleoptera, 1 species of  
 110 Diptera, and 3 species of Orthoptera), and 10 species of others (1 species of Hymenoptera, 4 species of Diptera, 1 species  
 111 of Lepidoptera, 1 species of Hemiptera, 1 species of Orthoptera, and 2 species of Homoptera). The ratio of natural enemies  
 112 (predator and parasitoid) to phytophages is 1.33: 1.

113 The diversity index (Shannon) of arthropods in the rice field ecosystem was fairly high (3.18) in comparison with  
 114 nearby dikes (3.04), bushes (3.06), and irrigation banks (3.13) but with the relatively low (<1) evenness index in sampling  
 115 places (0.70; 0.76; 0.79; and 0.81 for rice fields, dikes, bushes, and irrigation banks, respectively) indicating that the  
 116 richness between individuals is not even in every sampling site (Table 1). The higher the number of both indices indicate  
 117 that the arthropod community is more diverse in that particular place. The Margalef index (R) also suggests that the rice  
 118 field has the most arthropod species richness (11.09).  
 119



120  
 121 **Figure 3.** The composition of species and taxonomic of arthropods in rice field ecosystem in Puyung, Central Lombok.

122 **Table 1.** Arthropod diversity, evenness, and species richness indices in sampling area

Habitat	Shannon Index (H')	Pilou Index (E)	Margalef Index (R)
Rice field	3.18	0.70	11.09
Dike	3.04	0.76	7.40
Bushes	3.06	0.79	7.32
Irrigation bank	3.13	0.81	7.22

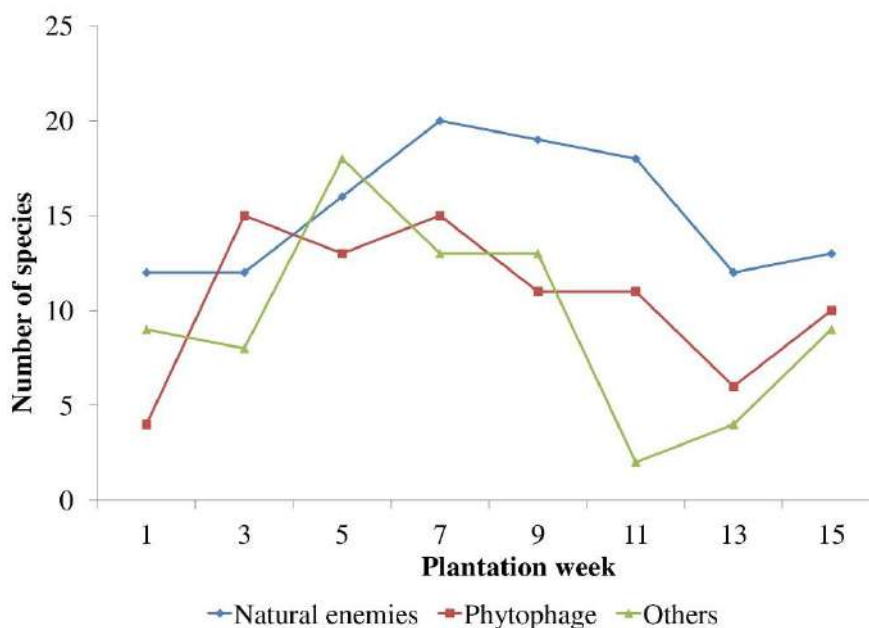
123 Observation data during the rainy season (December 2009–March 2010) showed that relative richness of phytophages  
 124 in rice fields was higher (51.38 %) than all of the other functional groups (Table 2). The different methods produced  
 125 different results: phytophage relative richness was 61.21 % in the net swing trap and 18.87 % in yellow pan trap.  
 126 Arthropoda that reside in vegetation were the mostly captured by the net-swinging method. The leaf locust *Atractamorcha*  
 127 *creatives* and *Oxya* sp. (both are Acrididae) were 74.16 % of all captured arthropods. *Pardosa* spiders, *Carabidae* bugs and  
 128 *Ocephylla smaragdina* ants were the most captured predators in the pitfall traps.

129 **Table 2.** Arthropod relative richness (%) in respective traps in rice field ecosystem

Functional groups	Relative richness (%)			
	Yellow pan trap (n = 2157)	Pitfall trap (n = 742)	Net swing (n = 8131)	Total (n = 11.030)
Phytophage	18.87	38.14	61.21	51.38
Predator	31.76	48.92	30.97	32.33

Parasitoid	5.52	1.08	2.12	2.71
Others	43.86	11.86	5.71	13.58
Total	100	100	100	100

130 Natural enemy arthropods increased with a similar pattern, but this increase was slower and had a lower relative  
 131 richness that peaked at 9–10 weeks after planting (Figure 4). After that, the richness of both phytophages and natural  
 132 enemies decreased until the last sampling, i.e. after the harvest.



133

134 **Figure 4.** The dynamics of arthropod species richness in rice field in Central Lombok during cultivation period from December 2009 to  
 135 March 2010.

### 136 Predator and parasitoid composition and richness

137 A total of 4039 predator individuals were observed during the study. Most of them were spiders (70.68 %) and insects  
 138 (29.22 %). A total of 13 species from 6 families of spiders were collected and Tetragnathidae, horizontal web spiders, were  
 139 the most abundant (22.7 % from total richness), followed by Araneidae (vertical web spiders), comprised about 21.9 % of  
 140 total richness; Oxyopidae, the diurnal hunter in plant spiders, comprised about 13.42 %; and 10.92 % were Lycosidae  
 141 (diurnal ground and plant hunter spiders). Salticidae (diurnal hunter in vegetation spiders) and Metidae (round horizontal  
 142 web spiders) were the least observed in this study, comprised only 1.61 % and 0.05 % of total richness, respectively.

143 At least 8 species from 5 predator spider families present in rice field ecosystems: Lycosidae (1 species), Oxyopidae (2  
 144 species), Salticidae (1 species), Lynipiidae (1 species), Araneidae (2 species), and Tetragnathidae (1 species). The high  
 145 relative richness may be caused by the high rainfall during the duration of the study, which suitable for spider's growth  
 146 and development. The monthly rainfall totals during December 2009 to April 2010 was 53, 317, 125, 249 and 152 mm,  
 147 respectively.

148 The relative richness of insects were 29.31 % from total predators. There were 20 species from 5 orders and 12 families  
 149 observed in this study. *Verania lineata* was the most sampled from Coccinellidae family and *Acupalpus smaragdulus*  
 150 *Febricius var. 5-pustulatus* Wiedemann (Carabidae) was the most trapped by the pitfall trap.

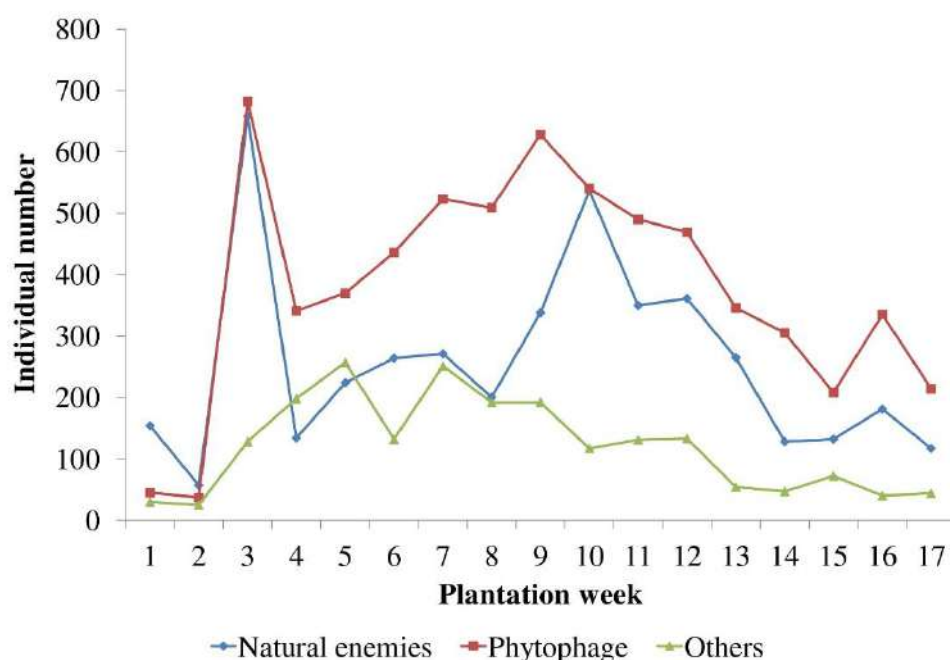
151 Parasitoids were not observed in great numbers and their ecological function was not as impactful than the predators,  
 152 based on their richness and diversity. A total of 172 individuals from several species were found; 5 species from  
 153 Hymenoptera; 2 species from Evaniidae; 1 species from Scelionidae; 1 species from Ichneumonidae; and 1 species from  
 154 Braconidae. The other parasitoid belonged to Sarcopagidae. Individuals of Evaniidae were the most abundant, 61.63 % of  
 155 total individuals sampled: *Prosevaria fuscipes* (67 individuals), *Megarhysa* (Ichneumonidae) (25 individuals), *Hadronatus*  
 156 sp. (Scelionidae) (24), Sarcopagidae (10) and *Meteorus nigricolis* (Braconidae) (4). The *Hadronatus* sp. seen is a  
 157 parasitoid of *Leptocorissa acutta*. More than 50 % arthropod species at first week after plantation were natural enemies of  
 158 pests (Fig. 4). About 29 belonged to predator species, 2 belonged to parasitoid species, 12 belonged to phytophage species  
 159 (28.57 % of all observed arthropods), and other arthropods were found. Lycosidae spiders were the most commonly found

160 (29.82 %), mainly *Hipassa* sp. and *Pardosa* sp. At the edge of the rice field, *Oecephylla smaragdina* ants and *Acupalpus*  
161 *pustulatus* were the most commonly found. Salticidae spiders were easily found on the bank of the irrigation channel.

### 162 Natural enemy and prey ratio

163 The ecological condition of an area can be inferred by analyzing the dynamic of sampled species ecological functions  
164 during the time of sampling. This study observed much more phytophages than their natural enemy in the half end of the  
165 study, but not in the first weeks of the study. The ratio of natural enemy and their phytophage prey from the first week  
166 until the third week of the plantation were 1:0.29; 1:0.65, and 1:1.01, respectively (Fig. 5).

167 Application of (2-Butan-2-ylphenyl) N-methylcarbamate (BPMC) insecticide one and two weeks after the rice planting  
168 resulted in lowering the relative richness of the arthropod community. Interestingly, phytophage relative richness increased  
169 much faster than did natural enemy richness after application. Herbicide application at 35 days after planting lowered the  
170 predator's relative richness but did not have any effect on phytophage richness. Phytophage relative richness increased  
171 gradually and reached its peak at 100–112 days after plantation. Carbamate insecticide application at 3 weeks after  
172 plantation lowered both natural enemy and phytophage relative richness, but phytophage relative richness was still higher  
173 than that of the natural enemies.



174

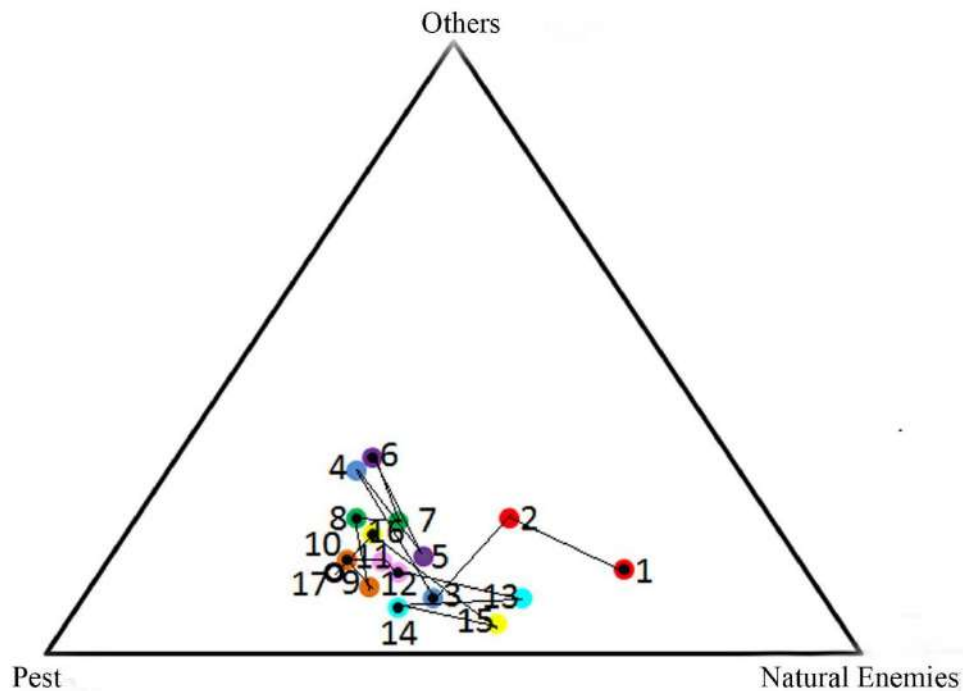
175 **Figure 5.** The population dynamics of phytophage, natural enemies and other insects caught in rice fields in Central Lombok during  
176 cultivation period from December 2009 to March 2010.

177 The natural enemy population slowly increased, with a similar pattern to the phytophages and reached its peak at 9–10  
178 weeks after planting. After that, both populations decreased until the harvesting time. Natural enemy relative richness  
179 significantly decreased during 15–21 days after planting and then increased following the trend of phytophage relative  
180 richness. The relative richness of both phytophages and natural enemies decreased during the harvesting time until the last  
181 sampling time at one week after harvest. In general, natural enemies were found from the first sampling time when the rice  
182 was planted. Total arthropods species during the first phase of rice growth (1 week after planting) were 25 species,  
183 increasing to 52 species at 7 weeks after planting, decreasing to 32 species at 14 weeks after planting, and 20 species at the  
184 harvesting time.

### 185 Environment endurance to pest organisms

186 In order to investigate the dynamics of the role composition of collected individual arthropod collected, across time or  
187 location within the same landscape, the pictorial analysis were done. This method is very suitable in understanding the  
188 ecological conditions associated with the development of preventive measures in pest management. The method used is in  
189 the form of a fictional approach by using a three-dimensional graphic to describe the position of the role composition. The  
190 analysis showed that, generalist predators such as *Pardosa* sp., *Oxyopes* sp., and *Oecephylla* ants were commonly found in  
191 the edge, irrigation bank, and bushes. Wild vegetation on the edge of the rice fields is considered as a reservoir for

192 predators such as spiders and Coccinellidae (Figure 6). Some of the wild vegetation on the edge was *Panicum* sp.,  
193 *Polygonum* sp., Amaranthaceae, Nasturtium, *Physalis angulata* and Echinochloa.



194

195 **Figure 6.** Ecological conditions of paddy fields by meal composition analysis pictorial role. The numbers inside the triangle indicate the  
196 observation times (there were 17 observations in this study).

## 197 Discussion

198 The total species number of sampled arthropods in the sampled rice fields during the planting period of 2009/2010 was  
199 98, much higher than what Arifin *et al.* (1997) observed in the same ecosystem in Central Java (56 species). Sampled  
200 arthropods belonged to 9 insect orders and 1 spider order. Sampling data indicated that Hymenoptera species were the  
201 most abundant and represented in almost every ecological function, including predator and parasitoids for rice pests and  
202 pollinators.

203 The species richness of natural enemies clearly outnumbered other functions (33 predators and 7 parasitoids) and  
204 comprised almost 40 % of all sampled arthropods. Arthropods species richness and high diversity index ( $H = 3.18$ ) suggest  
205 the balance of phytophages and their natural enemies, thus revealing the potential for natural pest control mechanism in the  
206 rice field ecosystems of Central Lombok. This finding is in accordance with Herlinda (2000). Relative species richness of  
207 arthropod community followed the growth of the rice in the ecosystem.

208 Hymenoptera parasitoids were mostly captured by yellow pan trap and predator class relative richness was fairly high  
209 in the rice field ecosystem (Table 2). This may due to the abundance of their prey and their high adaptability to the  
210 constantly changing environment. Similar resulted were documented by Settle *et al.* (1996) and Herlinda (2000). Besides  
211 that, predators have a high mobility range and a wide selection of prey. Among the predators, spiders were 70.68 % of the  
212 total predators and some of them were web spiders (Tetragnathidae and Araneidae) and the others were hunter spiders  
213 (Oxyiopidae and Lycosidae). Most of their reported prey are rice pests such as leaf and stem leafhoppers and other kinds  
214 of pest (Brown *et al.* 2003). Spiders were observed in all rice field plantation periods, from the seedling stage even until  
215 after harvest. The highest species richness was observed during the grain ripening period of rice, as most of the prey  
216 species of the spiders were present in this period. Coleoptera and Diptera were the second and third most observed orders  
217 in terms of relative richness of predators, while Hymenoptera and Hemiptera were less observed (1.73 % and 0.62 %,  
218 respectively). *Rhinocoris fuscipes* (Reduviidae, Hemiptera) are polyphage and potential predators for tobacco pests such as  
219 *Spodoptera litura* (Fab.) and Noctuidae (Sujatha *et al.* 2012).

220 Pollinator arthropods were the third largest category in term of relative richness and all of them were members of  
221 Hymenoptera: Vespidae, Halictidae, Anthophoridae, Cabronidae, Megachilidae and Sphecidae, with the most observed  
222 being Anthophoridae and Halictidae. Parasitoid and decomposers were the least observed in this study. Evaniidae were the  
223 most dominant parasitoid and some observed decomposers were Calliphoridae, Blatellidae, Blattidae, and Mantidae from  
224 Orthoptera. *Baetis haemalia* Leonard mayflies in Baetidae (Ephemeroptera) were observed and this family is widely  
225 observed as a bioindicator for water quality, environmental stress, and for evaluating the potential effect of climate change.



226 These Ephemeroptera live in clean and calm water surfaces and have micrositae with a wax layer on the tip of their legs  
227 that are very sensitive to water pollution. If Ephemeroptera is not found in the irrigation water body, it indicates that the  
228 water is polluted and have low water quality.

229 The composition of arthropod community is based on the plant phenology as the physical parts of the plant available  
230 for food and habitat impacts insect growth. Total species count of predators was always higher than pests in the vegetative,  
231 reproductive, and ripening states of the rice crop.

232 These study results suggest that many predators colonize the rice field ecosystem during the first phase of rice growth.  
233 Most of the spiders and predator insects seen were generalist predators during this phase. Lycosa spiders were usually  
234 present during the early vegetative state at the base of the rice plant and able to consume 5–15 individuals per day. *Oxiopes*  
235 sp. can consume up to three moths per day. Scenolidae and Braconidae had been found during the early phase, even  
236 though their relative population was small. Bambaradeniya and Edirisinghe (2008) also recorded the early presence of  
237 predators in the rice field ecosystem and the total species of phytophages increased faster than predators.

238 A total of 4 species were sampled from Lycosidae family (30.77 % of total species), 3 species from Araneidae, 2  
239 species from Tetragnathidae and Salticidae, and only 1 species sampled from the Matidae family. These four spiders are  
240 important generalist predators in rice field ecosystem with grasshoppers, flies, and moths as their main prey. Herlinda  
241 (2000) had similar results, in that relative richness of Tetragnathidae was the highest.

242 Lycosidae and Salticidae were observed from the first week after rice planting. Untill 6 weeks after rice planting, likely  
243 because the physical habitat is suitable to lay webs after 6 weeks from plantation. The first step to produce webs for most  
244 spiders is to select the place to lay the web and their webbing pattern is in part based on the physical aspect of the habitat.  
245 Prey availability and the supporting physical aspect of the habitat may contribute to the observed high relative richness of  
246 Tetragnathidae. Tetragnathidae were mainly found inside the rice plantation area rather than at the edges of the rice field.  
247 Araneidae were found from the first week after planting and their number increased, as the physical habitat was able to  
248 increase its support.

249 The diversity of arthropods was relatively dynamic as the changes, both in taxonomical aspect and ecological function,  
250 happened in a short time frame. More arthropods were found along with the further development state of the rice plants, as  
251 the habitat was more supportive for the growth and development for arthropods. The presence of arthropods was also in  
252 accordance with other environmental factors. Arthropod richness peaked at the seventh week after planting, when the rice  
253 plant started to produce grains and then decreased at the harvesting time. The results showed that Carabidae bugs, such as  
254 *Pherosopus occipitalis*, and dragonflies, such as *Orthotrum Sabina*, *Crocothemis servilia*, and *Copera* sp. were mainly  
255 found at the grain ripening timeframe, which may have been caused by the abundance of the prey during this time.

256 This study suggested that natural enemies could invade the ecosystem much faster when the pest population was still  
257 low. It may be caused by their wide range of prey, as the most commonly found natural enemy were generalist predators or  
258 parasitoid.

259 Pictorial analysis revealed that the Puyung rice field sampled during the planting period of 2009/2010 was not healthy.  
260 The natural enemy presence was dependent on the pest population as prey. In extreme condition, the natural enemy will go  
261 extinct if pest migration occurred. High relative richness at the edge of the rice field suggested that the wild vegetation was  
262 suitable habitat for the natural enemy. Karindah *et al.* (2011) stated that wild vegetation such as *Monochoria vaginalis*,  
263 *Fimbristylis miliacea*, *Cyperus iria*, and *Limnocharis flava* is able to sustain predator insects, especially *Metioche*  
264 *vittaticollis* and *Anaxipha longipennis*. The high similarity (67 %) of the arthropod community in the rice field and at its  
265 edge suggests species flow between rice field and the wild vegetation. Herlinda (2000) stated that the similarity of the two  
266 ecosystems suggests their interaction in terms of species flow. In some cases, a pictorial approach with a 3D graph can  
267 map the position and role composition (Triwidodo 2003).

## 268 CONCLUSION

269 The diversity of arthropods in rice field ecosystem in Puyung, Central Lombok showed quite high, namely 98  
270 species in 65 families and 10 orders, with a Shannon diversity index value of 3.18. The functional composition of species  
271 richness consisted of 33 predator species, 30 phytophage species, 10 pollinator species, 10 other arthropoda species, 8  
272 decomposer species, and 7 parasitoid species. The ratio of natural enemies with high phytophage groups at the beginning  
273 of the growth of rice plants, natural enemies found early in plant growth were generalist predators that do not depend on  
274 their main prey and could take advantage of alternative prey at that time. The fictional analysis showed that during the  
275 growth of rice plants, the arthropod inhabitants of rice fields in Puyung, Central Lombok were more abundance than the  
276 group of pests and natural enemies, and low of other insects. The existence of many natural enemies was supported by pest  
277 populations as a source of food.

## 278 CONFLICT OF INTEREST

279 All author declare that there are no conflict of interest in this research.

280

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282

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**[biodiv] Editor Decision**

1 pesan

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7 Oktober 2020 11.57

Balas Ke: Smujo Editors &lt;editors@smujo.id&gt;

Kepada: Ruth Stella Petrunella Thei &lt;rstellapt@gmail.com&gt;, Abdul Latief Abadi &lt;abadiabdullatief@gmail.com&gt;, Gatot Mudjiono &lt;gatotmudjiono@gmail.com&gt;, Didik Suprayogo &lt;suprayogod@gmail.com&gt;

Ruth Stella Petrunella Thei, Abdul Latief Abadi, Gatot Mudjiono, Didik Suprayogo:

We have reached a decision regarding your submission to Biodiversitas Journal of Biological Diversity, "Arthropod dynamic diversity in the rice field ecosystem in Central Lombok".

Our decision is: Revisions Required

Smujo Editors  
[editors@smujo.id](mailto:editors@smujo.id)

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Reviewer A:

Dear Editor,

Please find attached is the reviews and suggested edits for the manuscript "Arthropod dynamic diversity in the rice field ecosystem in Central Lombok".

This paper is written in very good English, so I enjoyed the reads. I also appreciate the extensive fieldwork conducted with a long period of data collection. While the findings of this study can enrich the existing knowledge in the field of agroecosystem entomology especially in the tropics, there are several things to clarify and improve the paper (as detailed in the attached document). In particular, things that became my concerns are:

1. In the Intro: There is a bunch of studies on arthropods in rice field ecosystems in indonesia. Even in the Biodiversitas Journal we can find several of them (e.g. Prabawati et al, 2019; Karenina et al, 2019; Herlinda et al 2020; etc). So, in the Intro I would suggest to review and elaborate those studies in one paragraph. Then, in a subsequent paragraph the author(s) can highlight the uniqueness/importance of the study. For example, the study can enrich the existing knowledge on agroecosystem entomology in tropics, particularly in the context of study area (i.e. Lombok Island) which might differ with the previous studies.
2. In the Methods: Please add map of study location (and inset map of Indonesia) as not all readers (e.g. non-Indonesians) are familiar with the region.
3. In the Results and Discussion: The parts that explaining Figures 1 and 2 are confusing since there are many inconsistencies between what presented in the figures, the figure captions, and in the text. For example, the caption of Figure 1 says the composition of species while the figure itself presenting ecological functions. Also, in the text said that there is 5 species and 3 families of Odonata, while Figure 2 suggests that there is only one species and family from this group. Please check again the consistency between the figure, figure caption and what explained in the text.
4. Where is the Supplementary Table 1? I can not find it in the document. Instead of put it as Supp. table , I would suggest to add the table as an appendix.
5. Figure 5: It is not directly clear what the figure tells about. I suggest to describe what pictorial role is about and how you did the analysis. Also, it is not clear what the numbers in the triangle refer to? Please add information/note about those numbers.

Best regards,

Reviewer

Recommendation: Revisions Required

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Biodiversitas Journal of Biological Diversity



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581K

# The dynamics of Arthropod diversity and abundance in rice field ecosystem in Central Lombok, Indonesia

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**Abstract.** *Thei RSP, Abadi AL, Mudjiono G, Suprayogo D. 2020. The dynamics of Arthropod diversity and abundance in rice field ecosystem in Central Lombok, Indonesia. Biodiversitas 21: 5850-5857.* Arthropods have roles as pests, decomposers, pollinators, and natural enemies of pests. Natural enemies play a vital role in pest population control by predation or parasitism. A study of the arthropod community in the rice field ecosystem was conducted in Central Lombok, Indonesia from December 2009 to March 2010 in order to elucidate the composition, structure, and dynamic diversity of arthropods present. Arthropod sampling was done by pitfall traps, yellow pan traps, and insect net. Arthropod dynamic diversity, especially of natural enemies, was determined by diversity index, dominance index, evenness analysis, and pictorial analysis. Based on taxonomical perspective, as many as 98 arthropod species were found, including 85 insect species from 59 families and 9 orders; and 13 spider species in 6 families. Based on the ecological functions, predator arthropods were the most common (33 species, dominated by spiders), but the phytophage arthropods had the most species richness (49.34%). A high Shannon index (3.18) and Pielou index (0.7) indicated dominant arthropods in the ecosystem. Arthropod species richness and diversity increased alongside rice development and decreased after harvest.

**Keywords:** Arthropods, diversity, rice field ecosystem, species richness

## INTRODUCTION

An agroecosystem, just like any other ecosystems, contains biotic and abiotic components that interact with each other which affect the growth and development of the biotic components (Altieri 1995). One of the biotic components of an agroecosystem is arthropods, which have roles in the ecosystem as pests, decomposers, pollinators, and natural enemies of pests. As pests would lower agricultural production, natural enemies are an important part of the ecological process as they can control pest populations through parasitism or predation.

In rice field agroecosystem, natural predators of pests are various and abundant (Bambaradeniya 2000). For example, Laba (2001) stated that no less than 700 species of insects, including parasitoids and predators, were found in rice field ecosystems without any pest infestations, such as brown leafhoppers. Settle et al. (1996) documented 765 spider species in a rice field ecosystem with irrigation in Indonesia. Bambaradeniya and Amerasinghe (2008) noted that spiders comprised more than 50% of arthropods in Sri Lankan rice fields. As many as 46 predators and 14 parasitoid species were found in rice fields in the Philippines (Heong et al. 1991). Those studies indicate that natural predators can adapt to continuously disturbed ecosystems such as in rice fields. The high adaptability of natural predators makes them feasible to be used in annual crop agroecosystems.

Nowadays, as agroecosystems become modernized, high energy inputs are often involved, including the use of

chemical fertilizers, pesticides, and other agricultural chemicals. The excessive use of those chemicals are already shown to cause pervasive ecological results and imbalances in the ecosystem. Imbalances in ecosystem are caused by poorly managed environment without regard to any ecological principles (Altieri and Nicholls 2004). Altieri and Nicholls (2004) stated that ecosystem management and agricultural practice may affect the diversity of predators and pests. This suggests that the lack of ecological balance and sustainability may cause continuous pest attack, erosion, water pollution, and so on. The uses of agricultural cultivation technologies and agrochemical applications are often harmed the natural enemies of the pests, depleting the ecological services provided by the agroecosystem and eventually collapsing the environment.

Some previous studies on arthropods in rice field ecosystems in Indonesia have been reported (Karenina et al. 2019; Prabawati et al. 2019; Herlinda et al. 2020; Wakhid et al. 2020). Prabawati et al. (2019) reported that the abundance of canopy arthropods in South Sumatra (Indonesia) freshwater swamp main and ratooned rice applied with bioinsecticides and synthetic insecticide. Karenina et al. (2019) showed that herbivore population and the lowest of spiders abundance in rice field ecosystems with synthetic insecticide application and significantly different with population in rice field ecosystems with refugia. The lowest of predatory insect abundance in plots with Abamectin applications reduced the parasitoid and herbivore number in freshwater swamps

of South Sumatra, Indonesia (Herlinda et al. 2020). Furthermore, the aquatic insect community in rice field ecosystems also reported in Bogor, West Java, Indonesia (Wakhid et al. 2020). However, there is little information about arthropods diversity and abundance of dynamics in rice field ecosystem in Central Lombok, West Nusa Tenggara Province, Indonesia. Our present study could enrich the existing knowledge on agroecosystem entomology in tropics, particularly in Lombok Island.

This study aimed to elucidate the diverse dynamic of arthropods in rice field ecosystems in Lombok Island and to reveal the community composition of pest and natural enemy arthropods in rice fields and the ecosystem surrounding them. We expected the results of this study can help the management of rice field ecosystems and the ecosystems surrounding them in hope to create greater sustainability.

## MATERIALS AND METHODS

### Study period and area

The study was conducted from December 2009 to March 2010. Arthropods were sampled in three acres of rice fields located in Puyung Village, Central Lombok District, West Nusa Tenggara Province, Indonesia (Figure 1). The seeding, planting, fertilization, and management of rice were based on local practices following the technical standards prescribed by company partner.

### Sampling methods

Sampling was performed starting from two weeks after rice planting until one week after harvest with a 14-day sampling interval. Swing nets (20 double swings) were used to sample arthropods in the plant canopy while 60 yellow pan traps with 3 repetitions were placed at an equal distance between them throughout the sampling area.

Ground surface arthropods were sampled by pitfall traps, with the same setting as the yellow pan trap (60 traps in total with 3 times repetition). All traps were set and collected after 24 hours. Every trapped arthropod was submerged in ethyl acetate, filtered out of the liquid with filter paper, rinsed with tap water, stored in 70% alcohol solution, and transferred to the laboratory for identification. Kalshoven (1981), Lawrence and Britton (1994), and Hadlington and Johnston (1987) manuals were used for sample identification and species identifications were recorded. Sample identification was performed at Mataram University and the Zoology Lab, Research Center for Biology, Indonesian Institute of Sciences (LIPI), Cibinong.

### Data analysis

Data were analyzed for: (i) diversity index (Eq. 1) (Rahayu et al. 2006); (ii) dominance index (Eq. 2); (iii) evenness index (Eq. 3) (Ludwig and Reynolds 1988); and species similarity (Eq. 4) (Southwood 1980).

$$H' = - \sum p_i \ln p_i \quad (1)$$

$P_i$  = Proportion of species  $i$

$$D = \frac{n_i}{N} \times 100\% \quad (2)$$

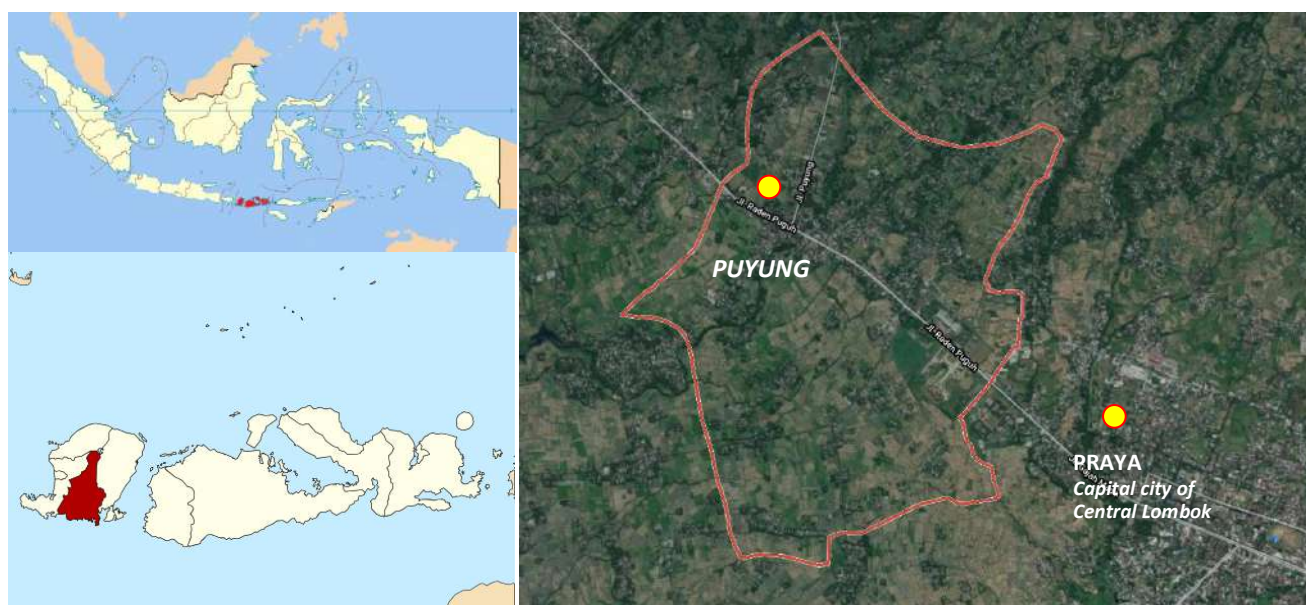
$N_i$  = Total of Species  $I$ ,  $N$  = Total sampled individual

$$E = H' / \ln(S) \quad (3)$$

$H'$  = Diversity index,  $S$  = Species count

$$C_s = 2j / (a + b) \quad (4)$$

Where;  $a$  = Total species in habitat  $a$ ,  $b$  = Total species in habitat  $b$ ,  $j$  = Total of same species found in  $a$  and  $b$  habitat



**Figure 1.** Map of study site in Puyung Village, Central Lombok District, West Nusa Tenggara Province, Indonesia area showing location of sampling sites (marked with black arrow)

**RESULTS AND DISCUSSION**

**Arthropods composition and richness based on taxonomy**

The Coleoptera (17 species from 8 families) was dominated by the Carabidae family (4 species) and Coccinellidae (3 species). Araneae was the third biggest arthropod group in the sample, consisting of 13 species in 6 families with Lycosidae and Araneidae as the most sampled family. Twelve species from 7 families of Hemiptera and 11 species from 11 families of Diptera were sampled during the study. Tetrigidae dominated in Orthoptera samples, with 8 species and 7 families. Cicadellidae was the dominating family from Homoptera (8 species and 6 families). The sampling found 5 species and 5 families of Lepidoptera and 5 species and 3 families of Odonata. Baetidae was the only family of Ephemeroptera collected during the sampling (Figure 2).

**Arthropods composition and richness based on ecological function**

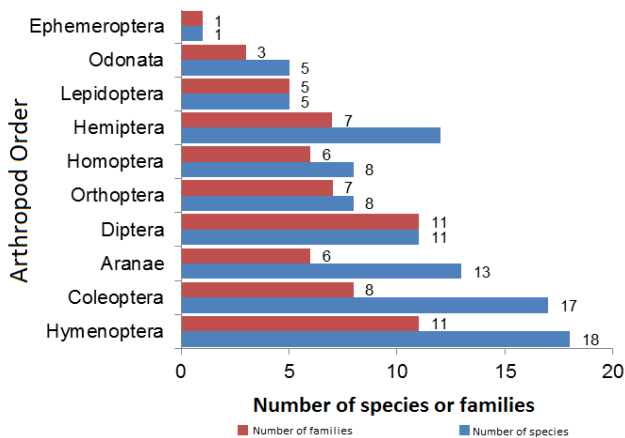
Based on their ecological function, all samples could be divided into 33 predator species, 7 parasitoid species, 30 phytophage species, 8 decomposers, 10 pollinators, and 10 arthropod species with other ecological functions (Figure 3). Based on ecological function, all obtained arthropods could be divided into 33 predator species (1 species of Hymenoptera, 7 species of Coleoptera, 4 species of Diptera, 3 species of Hemiptera, 5 species of Odonata, and 13 species of Araneae), 7 species of parasitoid (6 species of Hymenoptera and 1 species of Diptera), and 30 species of phytophage (6 species of Coleoptera, 1 species of Diptera, 4 species of Lepidoptera, 8 species of Hemiptera, 5 species of Orthoptera, and 6 species of Homoptera), 10 species of Hymenoptera of Pollinator, 8 species of decomposers (4 species of Coleoptera, 1 species of Diptera, and 3 species of Orthoptera), and 10 species of others (1 species of

Hymenoptera, 4 species of Diptera, 1 species of Lepidoptera, 1 species of Hemiptera, 1 species of Orthoptera, and 2 species of Homoptera). The ratio of natural enemies (predator and parasitoid) to phytophages is 1.33: 1.

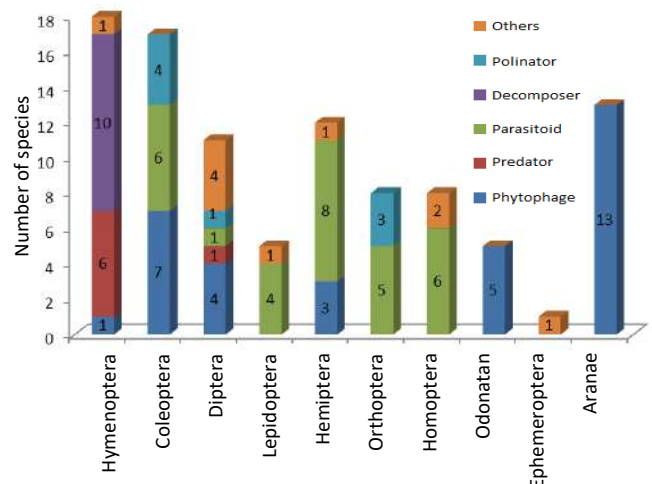
The diversity index (Shannon) of arthropods in the rice field ecosystem was fairly high (3.18) in comparison with nearby dikes (3.04), bushes (3.06), and irrigation banks (3.13) but with the relatively low (<1) evenness index in sampling places (0.70; 0.76; 0.79; and 0.81 for rice fields, dikes, bushes, and irrigation banks, respectively) indicating that the richness between individuals is not even in every sampling site (Table 1). The higher the number of both indices indicate that the arthropod community is more diverse in that particular place. The Margalef index (R) also suggests that the rice field has the most arthropod species richness (11.09).

Observation data during the rainy season (December 2009–March 2010) showed that relative richness of phytophages in rice fields was higher (51.38%) than all of the other functional groups (Table 2). The different methods produced different results: phytophage relative richness was 61.21% in the net swing trap and 18.87% in yellow pan trap. Arthropods that reside in vegetation were mostly captured by the net-swinging method. The leaf locust *Atractomorpha creatives* and *Oxya* sp. (both are Acrididae) were 74.16% of all captured arthropods. Pardosa spiders, Carabidae bugs, and *Oecephylla smaragdina* ants were the most captured predators in the pitfall traps.

Natural enemy arthropods increased with a similar pattern, but this increase was slower and had a lower relative richness that peaked at 9–10 weeks after planting (Figure 4). After that, the richness of both phytophages and natural enemies decreased until the last sampling, i.e. after the harvest.



**Figure 2.** The composition of Arthropod species based on ecological functions in the land of rice in Central Lombok, Indonesia



**Figure 3.** The composition of species and taxonomic of arthropods in rice field ecosystem in Puyung, Central Lombok, Indonesia



**Table 1.** Arthropod diversity, evenness, and species richness indices in sampling area

Habitat	Shannon Index (H')	Pilou Index (E)	Margalef Index (R)
Rice field	3.18	0.70	11.09
Dike	3.04	0.76	7.40
Bushes	3.06	0.79	7.32
Irrigation bank	3.13	0.81	7.22

**Table 2.** Arthropod relative richness (%) in respective traps in rice field ecosystem

Functional groups	Relative richness (%)			
	Yellow pan trap (n = 2157)	Pitfall trap (n = 742)	Net swing (n = 8131)	Total (n = 11.030)
Phytophage	18.87	38.14	61.21	51.38
Predator	31.76	48.92	30.97	32.33
Parasitoid	5.52	1.08	2.12	2.71
Others	43.86	11.86	5.71	13.58
Total	100	100	100	100

### Predator and parasitoid composition and richness

A total of 4039 predator individuals were observed during the study. Most of them were spiders (70.68%) and insects (29.22%). A total of 13 species from 6 families of spiders were collected and Tetragnathidae, horizontal web spiders, were the most abundant (22.7% from total richness), followed by Araneidae (vertical web spiders), comprised about 21.9% of total richness; Oxyopidae, the diurnal hunter in plant spiders, comprised about 13.42%; and 10.92% were Lycosidae (diurnal ground and plant hunter spiders). Salticidae (diurnal hunter in vegetation spiders) and Metidae (round horizontal web spiders) were the least observed in this study, comprised only 1.61% and 0.05% of total richness, respectively.

At least 8 species from 5 predator spider families present in rice field ecosystems: Lycosidae (1 species), Oxyopidae (2 species), Salticidae (1 species), Lynipiidae (1 species), Araneidae (2 species), and Tetragnathidae (1 species). The high relative richness may be caused by the high rainfall during the duration of the study, which suitable for spider's growth and development. The monthly rainfall totals from December 2009 to April 2010 were 53, 317, 125, 249, and 152 mm, respectively.

The relative richness of insects was 29.31% from total predators. There were 20 species from 5 orders and 12 families observed in this study. *Verania lineata* was the most sampled from Coccinelidae family and *Acupalpus smaragdulus Febricius* var. *5-pustulatus* Wiedemann (Carabidae) was the most trapped by the pitfall trap.

Parasitoids were not observed in great numbers and their ecological function was not as impactful as the predators, based on their richness and diversity. A total of 172 individuals from several species were found; 5 species from Hymenoptera; 2 species from Evaniidae; 1 species from Scelionidae; 1 species from Ichneumonidae; and 1

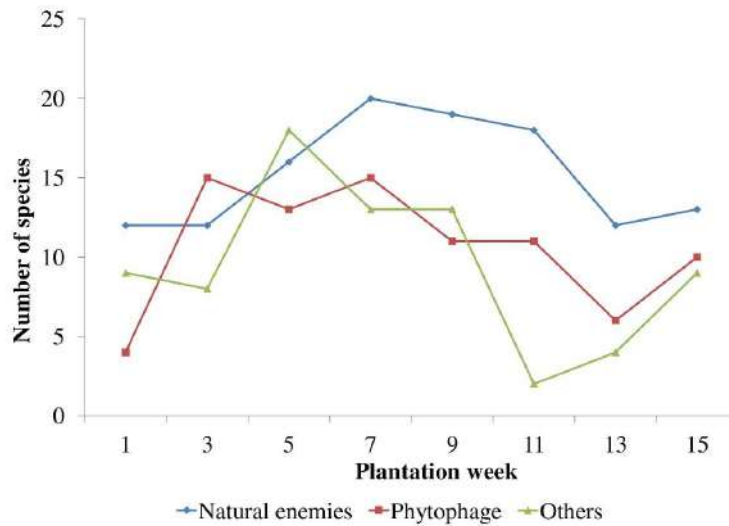
species from Braconidae. The other parasitoid belonged to Sarcopagidae. Individuals of Evaniidae were the most abundant, 61.63% of total individuals sampled: *Prosevaria fuscipes* (67 individuals), *Megarhysa* (Ichneumonidae) (25 individuals), *Hadronatus* sp. (Scelionidae) (24), Sarcopagidae (10) and *Meteorus nigricolis* (Braconidae) (4). The *Hadronatus* sp. seen is a parasitoid of *Leptocorissa acutta*. More than 50% of arthropod species at first week after plantation were natural enemies of pests (Figure 4). About 29 belonged to predator species, 2 belonged to parasitoid species, 12 belonged to phytophage species (28.57% of all observed arthropods), and other arthropods were found. Lycosidae spiders were the most commonly found (29.82%), mainly *Hipassa* sp. and *Pardosa* sp. At the edge of the rice field, *Oechephylla smaragdina* ants and *Acupalpus pustulatus* were the most commonly found. Salticidae spiders were easily found on the bank of the irrigation channel.

### Natural enemy and prey ratio

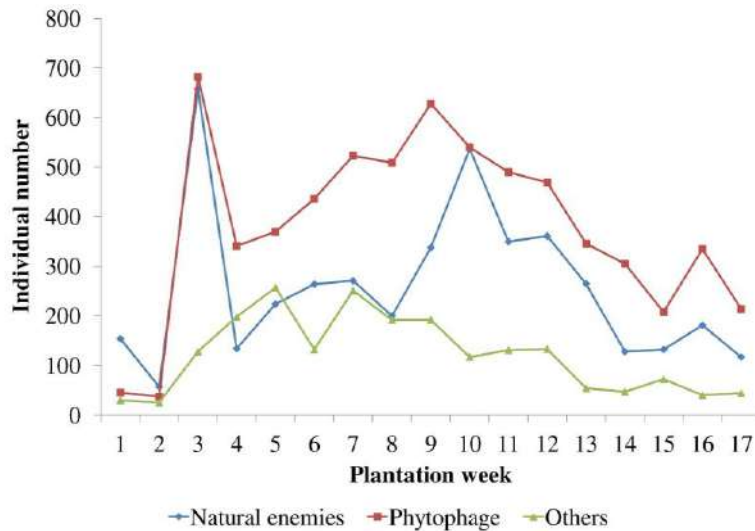
The ecological condition of an area can be inferred by analyzing the dynamic of sampled species ecological functions during the time of sampling. This study observed much more phytophages than their natural enemy in the half end of the study, but not in the first weeks of the study. The ratio of natural enemies and their phytophage prey from the first week until the third week of the plantation were 1:0.29; 1:0.65, and 1:1.01, respectively (Figure 5).

Application of (2-Butan-2-ylphenyl) N-methyl-carbamate (BPMC) insecticide one and two weeks after the rice planting resulted in lowering the relative richness of the arthropod community. Interestingly, phytophage relative richness increased much faster than did natural enemy richness after application. Herbicide application at 35 days after planting lowered the predator's relative richness but did not have any effect on phytophage richness. Phytophage relative richness increased gradually and reached its peak at 100–112 days after plantation. Carbamate insecticide application at 3 weeks after plantation lowered both natural enemy and phytophage relative richness, but phytophage relative richness was still higher than that of the natural enemies.

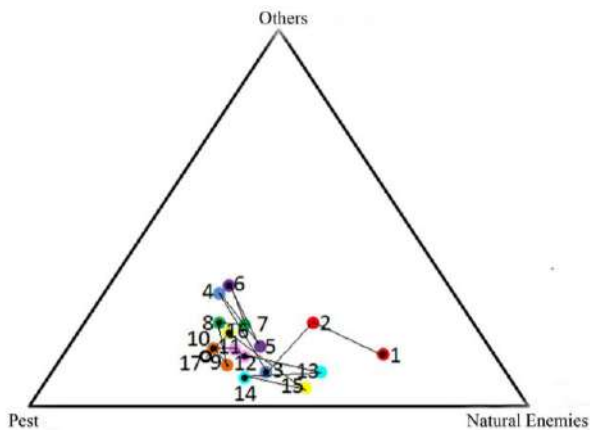
The natural enemy population slowly increased, with a similar pattern to the phytophages, and reached its peak at 9–10 weeks after planting. After that, both populations decreased until the harvesting time. Natural enemy relative richness significantly decreased during 15–21 days after planting and then increased following the trend of phytophage relative richness. The relative richness of both phytophages and natural enemies decreased during the harvesting time until the last sampling time at one week after harvest. In general, natural enemies were found from the first sampling time when the rice was planted. Total arthropods species during the first phase of rice growth (1 week after planting) were 25 species, increasing to 52 species at 7 weeks after planting, decreasing to 32 species at 14 weeks after planting, and 20 species at the harvesting time.



**Figure 4.** The dynamics of arthropod species richness in rice field in Central Lombok, Indonesia during cultivation period from December 2009 to March 2010



**Figure 5.** The population dynamics of phytophage, natural enemies, and other insects caught in rice fields in Central Lombok, Indonesia during cultivation period from December 2009 to March 2010.



**Figure 6.** Ecological conditions of paddy fields by meal composition analysis pictorial role. The numbers inside the triangle indicate the observation times (there were 17 observations in this study)

**Environment endurance to pest organisms**

In order to investigate the dynamics of the role composition of collected individual arthropod collected, across time or location within the same landscape, the pictorial analysis was done. This method is very suitable for understanding the ecological conditions associated with the development of preventive measures in pest management. The method used is in the form of a fictional approach by using a three-dimensional graphic to describe the position of the role composition. The analysis showed that, generalist predators such as *Pardosa* sp., *Oxyopes* sp., and *Oecophylla* ants were commonly found in the edge, irrigation bank, and bushes. Wild vegetation on the edge of the rice fields is considered as a reservoir for predators such as spiders and Coccinellidae (Figure 6). Some of the wild vegetation on the edge were *Panicum* sp., *Polygonum* sp., *Amaranthaceae*, *Nasturtium*, *Physalis angulata*, and *Echinochloa*.

## Discussion

The total species number of sampled arthropods in the sampled rice fields during the planting period of 2009/2010 was 98, much higher than what Arifin et al. (1997) observed in the same ecosystem in Central Java (56 species). Sampled arthropods belonged to 9 insect orders and 1 spider order. Sampling data indicated that Hymenoptera species were the most abundant and represented in almost every ecological function, including predator and parasitoids for rice pests and pollinators.

The species richness of natural enemies clearly outnumbered other functions (33 predators and 7 parasitoids) and comprised almost 40% of all sampled arthropods. Arthropod species richness and high diversity index ( $H= 3.18$ ) suggest the balance of phytophages and their natural enemies, thus revealing the potential for natural pest control mechanism in the rice field ecosystems of Central Lombok. This finding is in accordance with Herlinda (2000). Relative species richness of arthropod community followed the growth of the rice in the ecosystem.

Hymenoptera parasitoids were mostly captured by yellow pan trap and predator class relative richness was fairly high in the rice field ecosystem (Table 2). This may be due to the abundance of their prey and their high adaptability to the constantly changing environment. Similar results were documented by Settle et al. (1996) and Herlinda (2000). Besides that, predators have a high mobility range and a wide selection of prey. Among the predators, spiders were 70.68% of the total predators and some of them were web spiders (Tetragnathidae and Araneidae) and the others were hunter spiders (Oxyiopidae and Lycosidae). Most of their reported prey are rice pests such as leaf and stem leafhoppers and other kinds of pest (Brown et al. 2003). Spiders were observed in all rice field plantation periods, from the seedling stage even until after harvest. The highest species richness was observed during the grain ripening period of rice, as most of the prey species of the spiders were present in this period. Coleoptera and Diptera were the second and third most observed orders in terms of relative richness of predators, while Hymenoptera and Hemiptera were less observed (1.73% and 0.62%, respectively). *Rhinocoris fuscipes* (Reduviidae, Hemiptera) are polyphage and potential predators for tobacco pests such as *Spodoptera litura* (Fab.) and Noctuidae (Sujatha et al. 2012).

Pollinator arthropods were the third-largest category in terms of relative richness and all of them were members of Hymenoptera: Vespidae, Halictidae, Anthophoridae, Cabronidae, Megachilidae, and Sphecidae, with the most observed being Anthophoridae and Halictidae. Parasitoids and decomposers were the least observed in this study. Evaniidae were the most dominant parasitoid and some observed decomposers were Calliphoridae, Blatellidae, Blattidae, and Mantidae from Orthoptera. *Baetis haemalia* Leonard mayflies in Baetidae (Ephemeroptera) were observed and this family is widely observed as a bioindicator for water quality, environmental stress, and for evaluating the potential effect of climate change. These Ephemeroptera live in clean and calm water surfaces and

have micrositae with a wax layer on the tip of their legs that are very sensitive to water pollution. If Ephemeroptera is not found in the irrigation water body, it indicates that the water is polluted and has low water quality.

The composition of arthropod community is based on the plant phenology as the physical parts of the plant available for food and habitat impact insect growth. Total species count of predators was always higher than pests in the vegetative, reproductive, and ripening states of the rice crop.

These study results suggest that many predators colonize the rice field ecosystem during the first phase of rice growth. Most of the spiders and predator insects seen were generalist predators during this phase. *Lycosa* spiders were usually present during the early vegetative state at the base of the rice plant and able to consume 5–15 individuals per day. *Oxiopes* sp. can consume up to three months per day. Scenolidae and Braconidae had been found during the early phase, even though their relative population was small. Bambaradeniya and Edirisinghe (2008) also recorded the early presence of predators in the rice field ecosystem and the total species of phytophages increased faster than predators.

A total of 4 species were sampled from Lycosidae family (30.77% of total species), 3 species from Araneidae, 2 species from Tetragnathidae and Salticidae, and only 1 species sampled from the Matidae family. These four spiders are important generalist predators in rice field ecosystem with grasshoppers, flies, and moths as their main prey. Herlinda (2000) had similar results, in that relative richness of Tetragnathidae was the highest.

Lycosidae and Salticidae were observed from the first week after rice planting. Until 6 weeks after rice planting, likely because the physical habitat is suitable to lay webs after 6 weeks from plantation. The first step to produce webs for most spiders is to select the place to lay the web and their webbing pattern is in part based on the physical aspect of the habitat. Prey availability and the supporting physical aspect of the habitat may contribute to the observed high relative richness of Tetragnathidae. Tetragnathidae were mainly found inside the rice plantation area rather than at the edges of the rice field. Araneidae were found from the first week after planting and their number increased, as the physical habitat was able to increase its support.

The diversity of arthropods was relatively dynamic as the changes, both in taxonomical aspect and ecological function, happened in a short time frame. More arthropods were found along with the further development state of the rice plants, as the habitat was more supportive for the growth and development of arthropods. The presence of arthropods was also in accordance with other environmental factors. Arthropod richness peaked at the seventh week after planting, when the rice plant started to produce grains and then decreased at the harvesting time. The results showed that Carabidae bugs, such as *Pherosopus occipitalis*, and dragonflies, such as *Orthotrum sabina*, *Crocothemis servilia*, and *Copera* sp. were mainly found at the grain ripening timeframe, which



may have been caused by the abundance of the prey during this time.

This study suggested that natural enemies could invade the ecosystem much faster when the pest population was still low. It may be caused by their wide range of prey, as the most commonly found natural enemy were generalist predators or parasitoids.

Pictorial analysis revealed that the Puyung rice field sampled during the planting period of 2009/2010 was not healthy. The natural enemy presence was dependent on the pest population as prey. In extreme conditions, the natural enemy will go extinct if pest migration occurred. High relative richness at the edge of the rice field suggested that the wild vegetation was suitable habitat for the natural enemy. Karindah et al. (2011) stated that wild vegetation such as *Monochoria vaginalis*, *Fimbristylis miliacea*, *Cyperus iria*, and *Limnocharis flava* is able to sustain predator insects, especially *Metioche vittaticollis* and *Anaxipha longipennis*. The high similarity (67%) of the arthropod community in the rice field and at its edge suggests species flow between rice field and the wild vegetation. Herlinda (2000) stated that the similarity of the two ecosystems suggests their interaction in terms of species flow. In some cases, a pictorial approach with a 3D graph can map the position and role composition (Triwidodo 2003).

In conclusion, the diversity of arthropods in rice field ecosystem in Puyung, Central Lombok showed quite high, namely 98 species in 65 families and 10 orders, with a Shannon diversity index value of 3.18. The functional composition of species richness consisted of 33 predator species, 30 phytophage species, 10 pollinator species, 10 other arthropod species, 8 decomposer species, and 7 parasitoid species. The ratio of natural enemies with high phytophage groups at the beginning of the growth of rice plants, natural enemies found early in plant growth were generalist predators that do not depend on their main prey and could take advantage of alternative prey at that time. The fictional analysis showed that during the growth of rice plants, the arthropod inhabitants of rice fields in Puyung, Central Lombok were more abundant than the group of pests and natural enemies, and low of other insects. The existence of many natural enemies was supported by pest populations as a source of food.

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Ahmad Dwi Setyawan

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