Temporal effects of forest thinning on spring tails (Entomobryomorpha: Collembola) assemblages at pulai (Alstonia scholaris) forest plantation in Banten

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Abstract. Forest thinning affects the forest ecosystem, which changes abundance and diversity of insect species, including ground insects. This study aims to measure and analyze the effects of forest thinning on diversity of Entomobryomorpha at pulai (Alstonia scholaris) forest plantation. The study was carried out in thinning compartment of 15.30 ha. Eight circular sample plots with a radius of 17.8 m were placed systematically in the thinning compartment with a distance between plots of 45 m. A square subplot of 1m x 1m was placed in the center of each circular plot. Five pitfall traps were installed in the subplot. Insects were harvested before forest thinning and 7 days after forest thinning. Mann Withney test was used to compare the abundance and composition of morphospecies of Entomobryomorpha before and after forest thinning. Pearson correlation test was used to measure the correlation between insect abundance and environmental factors. Forest thinning decreased the morphospecies composition of Entomobryomorpha and increased the abundance of Entomobryomorpha insects. The abundance of the Entomobryomorpha order correlated significantly with humidity, litter thickness, and canopy cover.

1. Introduction
Development of industrial timber plantation (ITP) in Indonesia aims to provide raw materials for wood based-industry and reduces pressure on natural forests. There are various types of ITP in Indonesia, such as ITP for fiber wood, veneer and sawn timber wood, and energy wood [1]. Species that mostly planted at ITP is fast growing species, such as mangium (Acacia mangium), eucalyptus (Eucalyptus deglupta), sengon (Albizia Chinensis), and pulai. Pulai (Alstonia scholaris) has good prospects for the development of timber plantations, because demand of pulai tends to increase and pulai can be used to produce wide range of wood products, such as crates, matches, shoe hill, handicrafts, concrete molds, pencils slate and pulp [2].

Forest thinning is one of forest tending activities, which are carried out to increase quality of timber plantation stand. Forest thinning aims to provide better space for tree growth, improve forest health, eliminate trees with poor quality, and provide financial returns [3], [4]. Forest thinning is partial cutting, so it has potential impact on the forest environment. Previous study showed that forest thinning effects distribution, composition, and activity of biotic resources, including soil biological communities [5], [6].

Insect belongs to biotic resources, which is dominant fauna with nearly 80 percent of the total number of fauna on the earth. Total number of insect species is predicted about 751,000 species worldwide. Around 250,000 species of them are found in Indonesia. Entomobryomorpha is one of the
orders of spring tail insect (Collembola). Entomobryomorpha plays an indirect role in the decomposition of organic matter, indicator of changes in soil conditions, and indicator of ecosystem balance [7],[8],[9],[10]. Change of insect diversity will disturb all processes in the food webs [11]. Study on the effects of forest thinning on the abundance of Entomobryomorpha in Indonesia is rare, both in natural forests and in timber plantations. Previous study on Collembola in Indonesia has been carried out in the certain habitat or certain land use patterns, such as oil palm plantations, agriculture, and settlements [12],[13],[14],[15]. While in the forestry field, study on the effects of forest management (including forest thinning) on Collembola is limited. The relationship between soil fauna and drained peatland has been examined for industrial forest plantations in Indonesia [16]. Therefore, this study aims to measure and analyze the effects of forest thinning on the diversity of Entomobryomorpha.

2. Material and Methods
The study was carried out in the thinning compartment of 31A plot, forest management unit of Gunung Kencana, Banten. The study was carried out in the dry season period (June-August) in 2019. Geographically, the study site was located at 5°7'50"-7°1'11" SL and 105°1'11"-10°6'7"12" EL. The topography of the study site varied from flat to steep. Altitude of compartment 31A was 500 m asl. The type of soil at the study site was podzolik. Average rainfall at the study site was 2,500 mm/year and daily temperatures ranged from 30-40°C. The area of compartment 31A was 15.30 ha, which was planted with pulai (Alstonia scholaris) in 2009. Pulai forest was thinned with intensity of 45%. Thinning intensity is the ratio between the number of trees before thinning and the number of trees after thinning.

Eight circular plots with radius of 17.8 m were placed systematically in the thinning compartment with a distance between plots of 45 m. A rectangular sub-plot of 1 m x 1 m was placed in the center of the circular plot. Insect was collected using pitfall traps. Five pitfall traps were installed in 1 m x 1 m sub plot, 4 pitfall traps in each corner of the sub plot and one pitfall trap in the center of the sub plot. Insect was harvested before forest thinning and a week after forest thinning. Insect was identified to the morphospecies level [17].

Environmental factors, such as canopy cover, temperature, humidity, number of understorey plants, and litter thickness, were measured before forest thinning and after forest thinning. Measurement of environmental factors were took place at the pitfall trap installation point. Entomobryomorpha insect community parameters, which include abundance, species diversity index of Shannon-Wiener (H'), species richness index of Margalef (DMg), evenness index (E), and morisita index of Krebs (Id), were calculated to compare Entomobryomorpha assemblages before forest thinning and after forest thinning. Mann-Whitney non-parametric test was used to test differences in the abundance and morphospecies composition of Entomobryomorpha before forest thinning and after forest thinning at the significant level of 10%. Pearson correlation test was used to examine the relationship between the abundance of Entomobryomorpha insects and environmental factors at 10% significance level.

3. Result and Discussion
A total of 701 individual Entomobryomorpha insects were found before forest thinning and after forest thinning. The abundance of Entomobryomorpha insects after forest thinning was higher than before forest thinning. The abundance of Entomobryomorpha before forest thinning was 314 individuals, consisting of 3 families and 12 morphospecies. The abundance of Entomobryomorpha after forest thinning increased to 387 individuals, consisting of 2 families and 10 morphospecies (Figure 1). The morphospecies composition of Entomobryomorpha changed after forest thinning. There was one new morphospecies (Papiroides sp.), which was found only after forest thinning, and three morphospecies that were not found after forest thinning, i.e Callytrura sp., Folsomides sp., and Pseudoparanella sp. Number of morphospecies of Entomobryomorpha, that was found both before forest thinning and after forest thinning was 9 morphospecies (Table 1).
Figure 1 Number of families and morphospecies of Entomobryomorpha before forest thinning and after forest thinning at pulai forest stand in Banten

| Morfospesies                  | Abundance before forest thinning | Abundance after forest thinning |
|-------------------------------|----------------------------------|---------------------------------|
| Morfospesies which found both before and after forest thinning |                                   |                                 |
| Acrocyrtus sp.                | 18                               | 59                              |
| Ascocyrtus sp.                | 29                               | 65                              |
| Coecobrya sp.                 | 95                               | 69                              |
| Cyphoderopsis sp.             | 11                               | 28                              |
| Heteromurus sp.               | 49                               | 38                              |
| Homidia sp.                   | 3                                | 1                               |
| Lepidocyrtus sp.              | 22                               | 2                               |
| Pseudosinella sp.             | 31                               | 67                              |
| Rambutsinella sp.             | 39                               | 55                              |
| Morfospesies which found only before forest thinning |                                   |                                 |
| Callyntrura sp.               | 11                               | 0                               |
| Folsomides sp.                | 1                                | 0                               |
| Pseudoparonella sp.           | 5                                | 0                               |
| Morfospesies which found after forest thinning |                                   |                                 |
| Papiroides sp.                | 0                                | 3                               |

The abundance of Entomobryomorpha increased 23% after forest thinning. The difference in abundance and in morphospecies composition of Entomobryomorpha between before forest thinning and after forest thinning was not statistically significant (P-value > 0.10). Species diversity index, species richness index, evenness index and morosita index of Entomobryomorpha after forest thinning were smaller than before forest thinning (Figure 2). Index of species richness of Entomobryomorpha before forest thinning was 1.91 and after forest thinning 1.51. The evenness index of Entomobryomorpha before forest thinning was 0.80 and after forest thinning 0.76. The result showed that there was dominance of Entomobryomorpha insects, both before forest thinning and after forest thinning (E<1). Coecobrya sp. was a morphospecies of Entomobryomorpha that dominates at pulai plantation before forest thinning and after forest thinning. The previous studies showed that Coecobrya were cosmopolitan genera [18], and species of this type were usually associated with...
eutrophic habitat [19]. The distribution pattern of Entomobryomorpha before forest thinning and after forest thinning was clustered. The morisita index of Entomobryomorpha was higher than 1 both before forest thinning and after forest thinning.

![Figure 2](image)

**Figure 2** Diversity index (H'), species richness index (DMg), evenness index (E), and morisita index (Id) of Entomobryomorpha before forest thinning and after thinning at pulai forest stand in Banten

Forest thinning increased temperature, number of understory plants and litter thickness, and decreased air humidity and canopy cover. Average daily air temperatures increased by 1.8 °C after forest thinning. The air temperature before forest thinning was 30.5 °C and after forest thinning 31.2 °C. Forest thinning reduced air humidity by 6.6%. Air humidity before forest thinning was 66.2% and after forest thinning 59.6%. Percent of canopy cover decreased by 3.42% after forest thinning. The canopy cover before forest thinning was 14.2% and after forest thinning 10.8%. Forest litter thickness increased by 2.3 cm after forest thinning. The average litter thickness before forest thinning was 4.3 cm and after forest thinning 6.6 cm.

Table 2 showed the correlation between abundance of Entomobryomorpha and environmental factors at pulai forest stands in Banten. The abundance of Entomobryomorpha was negatively correlated with temperature, number of understory plants, and percentage of canopy cover, and positively with humidity and litter thickness. Result of the study showed that there was a significant correlation between abundance of Entomobryomorpha and air humidity, litter thickness, and percent of cover canopy, but did not correlate significantly with air temperature and number of understory plants.

**Table 2** Correlation between abundance of Entomobryomorpha and environmental factors at pulai forest stands in Banten

| Variable | T | RH | LT | UP | CCO |
|----------|---|----|----|----|-----|
| Abundance| CC | -0.17ns | 0.20 | 0.40 | -0.05ns | -0.47 |
|          | P  | 0.12 | 0.07* | 0* | 0.64 | 0* |

Note: T= temperature; RH= humidity, LT= litter thickness; UP= number of understorey plant; CCO= canopy cover; CC= correlation coefficient; P = probability; ns= not significant; *= significant

Study on effects of forest thinning on Entomobryomorpha in Indonesia is limited. Previous studies in temperate countries showed that silvicultural practices, including forest thinning, affect invertebrate on the forest floor [20], [21]. The abundance of soil and litter arthropods was higher after two years of forest harvesting [22]. Furthermore, microarthropod densities in opener forests are higher than
closed forests [23]. The study obtained similar results to previous studies. The abundance of Entomobryomorpha increased after forest thinning. Increasing in abundance of Entomobryomorpha was predicted due to the accumulation of litter on the forest floor after forest thinning. Forest litter is a preferred habitat and source of food for Entomobryomorpha insects. In addition, most of Entomobryomorpha lives in hidden places such as under felled trees, under bark, and rotted wood. Although the abundance of Entomobryomorpha changed due to forest thinning, there was no significant difference in abundance between before forest thinning and after forest thinning (P> 0.1). The abundance of Entomobryomorpha tend to increase after thinning operation. Humidity, forest litter thickness, and canopy cover could be a determinant factors for abundance of Entomobryomorpha after thinning. In addition, insignificant difference in abundance of Entomobryomorpha before and after thinning can be caused by small sample size and short observation period (7 days after thinning).

The result of the study showed that forest thinning did not significantly affect the morphospecies composition of Entomobryomorpha (P>0.1). Thinning of pulai forest changed in morphospecies composition of Entomobryomorpha. The result showed that morphospecies of Entomobryomorpha has different responses to habitat changes due to forest thinning. The majority of Entomobryomorpha morphospecies were not susceptible to habitat change due to forest thinning. There were nine Entomobryomorpha morphospecies found both before forest thinning and after forest thinning (Table 1). This study obtained similar result to previous studies. The results of previous studies indicated that forest thinning has a non-severe effect on habitat of some insects, so that the majority of species still survive in their disturbed habitat [18]. The effect of forest harvesting on soil organisms occurred in the short term [5] and the composition of microarthropod species does not change much after forest harvesting [23]. Species diversity index, species richness index, evenness index and morosita index of Entomobryomorpha decreased after forest thinning (Figure 2). There were dominant Entomobryomorpha found before forest thinning and after forest thinning. The pattern of Entomobryomorpha distribution at the pulai stands in Banten was clustered. The diversity of Entomobryomorpha at pulai plantations was relatively low. Forest thinning altered species richness index.

The results showed that there were a positive relationship between the abundance of Entomobryomorpha with air humidity, litter thickness and canopy cover. Previous studies have shown that large amount of litter accumulation on the forest floor became a food source for Entomobryomorpha [9, 14], so the abundance of Entomobryomorpha was greater after forest thinning. Entomobryomorpha had sensitive respon to soil moisture changes, both on the surface and in the soil. Soil moisture also indicated soil water content around habitat of Entomobryomorpha [24]. Humidity has an important role in determining the distribution pattern of Entomobryomorpha. Soil moisture content played a major role in the distribution of Entomobryomorpha [9]. Although air humidity after thinning decreased, the abundance of Entomobryomorpha increased after thinning. It is suspected that the increase in abundance was temporary. The period of observation after thinning was very short, i.e one week after thinning. Forest harvesting would have only minimal and short-term effects on microclimate of the forest floors [5], [6]. Long-term time-since-harvesting had no effect on differences in humidity between cut and un-cut sites in temperate zones. There was a significant difference in temperature between harvested forests and non-harvested forests, the average difference was generally small (<1°C) [6]. The study obtained similar result to previous studies. The average difference in temperature before forest thinning and after forest thinning at pulai stand in Banten was 0.52°C.

4. Conclusion
The effect of forest thinning on Entomobryomorpha was different. The majority of Entomobryomorpha were vulnerable to habitat change due to forest thinning. Thinning of pulai plantations increased abundance and decreased morphospecies composition of Entomobryomorpha. The abundance and morphospecies composition of Entomobryomorpha insects before thinning were not different from after thinning. The abundance of Entomobryomorpha had a significant correlation with litter thickness, air humidity, and canopy cover. To determine the long-term effect of thinning forests on Entomobryomorpha, additional study is needed.
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