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Short Communication: Effects of felling intensity on Hymenoptera biodiversity in a natural production forest in East Kalimantan, Indonesia

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Abstract. *Ahmad B, Haneda NF, Robaikah ID. 2016. Short Communication: Effects of felling intensity on Hymenoptera biodiversity in a natural production forest in East Kalimantan, Indonesia. Biodiversitas 18: xxxx*. Hymenoptera is one of the major components of insect biodiversity, where its abundance and diversity contributes to the functioning of the forest ecosystem. Most of the tropical forest in Kalimantan island has been logging since 1970. Tree felling is the initial step of logging activity. This activity leads to change Hymenoptera diversity. This study analyzes the effects of felling intensity on the Hymenoptera diversity in 100 ha area in a natural production forest in East Kalimantan, Indonesia. In this study, the diversity, evenness, and species richness index of Hymenoptera was compared before and after felling in three intensities (low, moderate, and high). Insects were collected in 9 purposively located 0.5 ha plots using a malaise trap. Three malaise traps were set in each plot The results showed that the timber felling tends to decrease the abundance of Hymenoptera. Diversity and species richness of Hymenoptera will decline in moderate and high felling intensity, whereas evenness index of Hymenoptera unchanged at three felling intensities. The composition of morphospecies of Hymenoptera was changed after tree felling with high intensity. The results of the study suggest that minimizing the felling intensity may reduce disruption of insect habitat in natural production forest in East Kalimantan, Indonesia.

Keywords: Biodiversity, felling intensity, Hymenoptera, natural production forest

INTRODUCTION

Tree felling is a part of forest harvesting and a critical activity of forest harvesting that determines the initial damage of forests since this activity has impacts on the residual stands, soil, water and wildlife (Session 2007). One of the wildlife that will be disturbed by tree felling is the insect groups. Hymenoptera is one of the four largest orders of insects. Some groups of hymenopteran insects such as ants, bees, and parasitoids play an important role in forest ecosystems (Yaherwandi et al. 2006). In addition, some species of insects have the potential to be used as biological indicators for the assessment of ecosystem changes (Jurzenski et al. 2012; Wicaksono et al. 2011).

The effects of forest harvesting on wildlife vary, depending on the intensity of harvesting (Medjibe et al. 2011). Wilson and Wilson (1975) reported that felling intensity of 8-10 trees ha^{-1} caused relatively small changes in primate populations. Meanwhile, Johns (1983) found that felling intensity of about 18 trees ha^{-1} led to a considerable decrease in primate populations and significant damage to the forest. Yoshimura (2012) reported that the impacts of forest harvesting on insects are a decrease in diversity and abundance of insects and disruption to the ecology of the forest).

The studies of the impacts of timber harvesting on biodiversity were more focused on the biodiversity of flora and residual stand (Budiaman and Pradata 2013; Macpherson et al. 2010; Putz et al. 2008), while on fauna the focus is more on vertebrates, such as mammals (Klenner and Sullivan 2009; Sullivan and Sullivan 2012; Yamada et al. 2014), birds (Campbell and Witham 2007; Holmes 2007), reptile (Semlitsch 2009; Todd and Adrews 2008). There have not been many studies of the impacts of forest harvesting on invertebrates, particularly in the level of invertebrate communities (Hawthorne et al. 2011). Therefore, the aim of the research was to analyzes the effects of timber harvest on the Hymenoptera diversity in a natural production forest in East Kalimantan, Indonesia.

MATERIALS AND METHODS

Study area

Fieldwork was conducted in one of the natural production forest concessions in Mahakam Ulu District, East Kalimantan, Indonesia, in 2016 (Figure 1). The forest has been logged using the silvicultural system of the Indonesian Selective Cutting and Planting System in 1973. The topography of the study area was varied from flat to undulating. The study was conducted in a wet climate, and the average of monthly rainfall was 312 mm and an average temperature of 26.4°C.

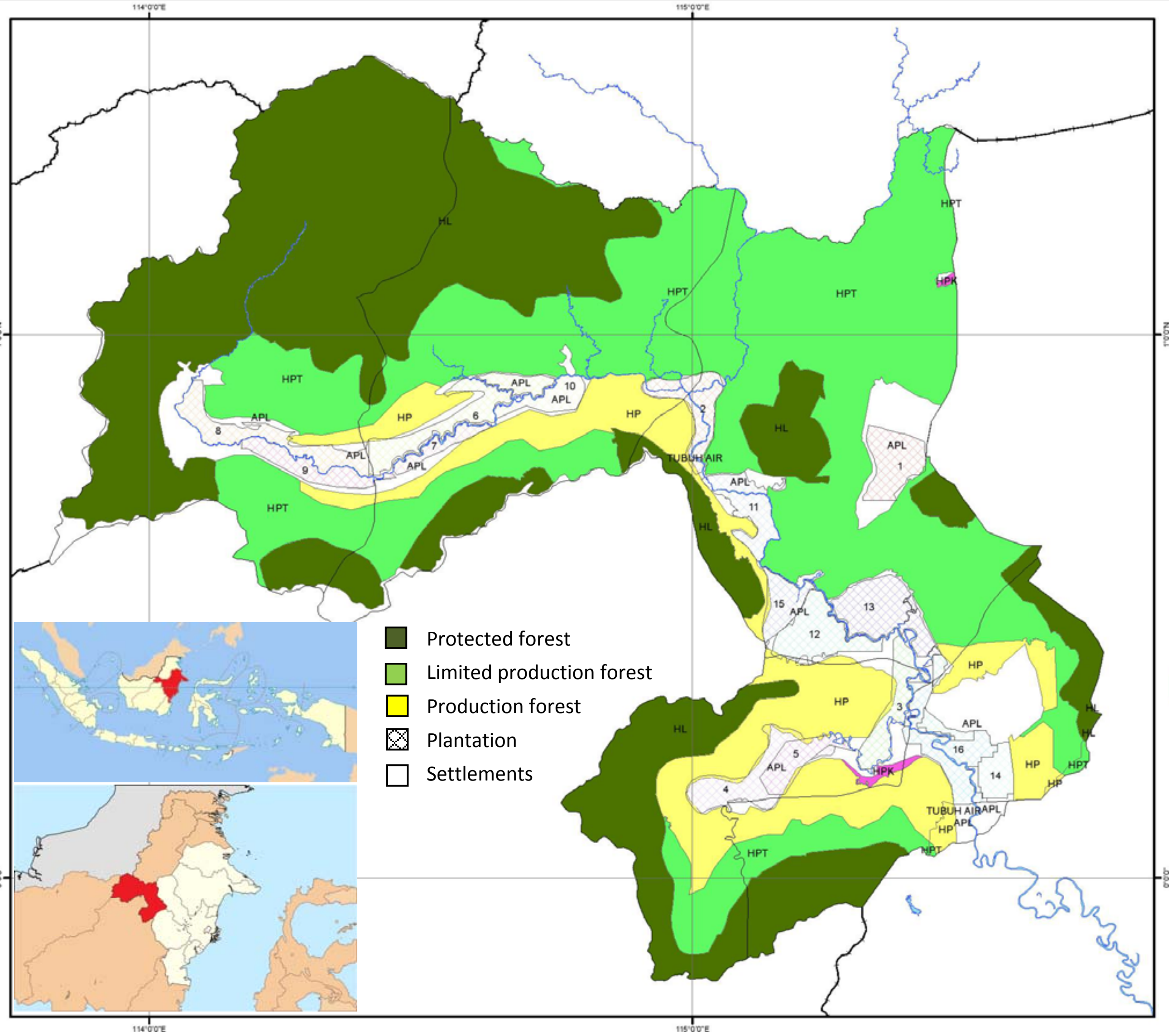

Figure 1. Research location, Mahakam Ulu District, East Kalimantan, Indonesia

Procedures

The form of plot applied was a circular plot with an area of 0.5 ha plot^{-1}. The plot was purposively placed in a felling compartment which covered about 100 hectares. The plots were divided into three felling intensity, namely low (≤ 5 trees ha^{-1}), moderate (6-10 trees ha^{-1}), and high (> 10 trees ha^{-1}). The felling intensity was obtained by dividing the number of felled trees plot^{-1} (trees ha^{-1}). In each class, three plots were established. The insects were collected using a malaise trap. All insects collected were identified to morphospecies. The sampling of hymenopteran insects was done two days before and after the tree felling. The canopy cover, temperature, and air humidity were measured two days before and after the felling.

Data analysis

The species diversity, species richness, and evenness index were calculated by (Magguran 1988): $H' = -\Sigma$ (P ln P), $P = n.N^{-1;}$ $DMg = (S-1).(\ln N)^{-1;}$ $E = H'.(\ln S)^{-1;}$ where H' = Shannon-Wiener species diversity index, n = number of individuals of each species, N = number of individuals of all species, DMg = Margalef species richness index, and E = evenness index. The t test was applied to define differences in the species abundance at three felling intensities. Friedman test was applied to define differences in the morphospecies composition of the hymenopteran insects before and after felling at the 95% confidence level. Pearson's correlation test was employed to determine a correlation between the abundance of hymenopteran insects and canopy cover, temperature and air humidity.

RESULTS AND DISCUSSION

Abundance of Hymenoptera

The tree felling led to the decrease of the abundance of hymenopteran insects in three felling intensities, which amounted to 11% in low-intensity felling, 25% in moderate-intensity felling and 49% in high-intensity felling (Figure 2).

The results of the t test showed that only high-intensity felling affected significantly on the abundance of hymenopteran insects before and after tree felling (α = 20%) (Table 1). Based on the Friedman test results, it is identified that the morphospecies composition before and after felling is not significantly different in low- and moderate-intensity felling ($p > 0.05$), but significantly different in the high-intensity felling (Table 2).

Diversity and evenness index

The species diversity index of hymenopteran insects seemed to increase in the low-intensity felling but decreased in the moderate-intensity and high-intensity felling (Figure 3). The species richness index of hymenopteran insects appeared to have an increase in the low-intensity felling but experienced a decrease in the moderate-intensity and high-intensity felling (Figure 4). The evenness index of hymenopteran insects seemed to increase after felling in any felling intensity (Figure 5).

The average temperature, humidity, canopy cover and abundance of hymenopteran insects before and after felling in three felling intensities is presented in Table 3.

Pearson's correlation test results showed that the temperature, humidity and canopy cover did not have a close correlation with the abundance of hymenopteran insects ($P > 0.05$). The test results showed that humidity and canopy cover had a unidirectional relationship with the abundance of hymenopteran insects, while the temperature had a relationship that was not unidirectional with the abundance of hymenopteran insects (Table 4).

The study found 30 hymenopteran families at the research site. A total of 357 individual insects from the Formicidae family were found, 288 individual insects were from the Ichneumonidae family, and from the Braconidae family, 101 individual insects were found. The dominant morphospecies from the Formicidae family at the research site was *Stigmatomma* sp. and *Cerapachys* sp. The dominant morphospecies from the Ichneumonidae family was *Pimpla* sp., *Setanta* sp. and *Gelis* sp., while the dominant morphospecies from the Braconidae family was *Orgilus* sp.

Table 1. t-test results for means of abundance of hymenopteran insects in three felling intensities

Felling intensity	BF	AF	(BF-AF)
Low	62,0	55,3	6,7^{ns}
Moderate	76,7	57,7	19,0^{ns}
High	66,3	34,0	32,3*

Note: * significance at $p < 0.20$, ns = non significance, BF=Before felling, AF=After felling.

Table 2. Friedman test results for the morphospecies composition of hymenopteran insects in three felling intensities

Intensity	Chi-Square	Probability
Low	1.080	0.299^{ns}
Moderate	1.563	0.211^{ns}
High	4.765	0.029*

Note: * significance at $p < 0.05$, ns = non significance

Table 3. Average temperature, humidity, canopy cover and abundance of hymenopteran insects before and after felling in three felling intensities

Felling intensity	Before felling				After felling			
	A	T	RH	CC	A	T	RH	CC
Low	62	32	75	82	55	32	77	59
Moderate	77	30	76	84	58	33	75	62
High	66	31	79	79	34	33	78	54

Note: A= Abundance (individual), T: Temperature (°C), RH: humidity (%), CC: Canopy cover (%)

Table 4. Pearson correlation test results for means of temperature, humidity, canopy cover and the abundance of hymenopteran insects in three felling intensities (Cc/p)

Parameter	Parameter		
	Temperature	Humidity	Canopy cover
Abundance	(-)0.418/0.085**	0.290/0.244^{ns}	0.463/0.053**
Temperature	-	(-)0.836/0.000*	(-)0.397/0.103^{ns}
Humidity		-	0.004/0.987**

Note: * significance at $p < 0.01$, ** significance at $p < 0.10$, ns = non significance, (-)= negative correlation, Cc/p= Correlation coefficiient/probability

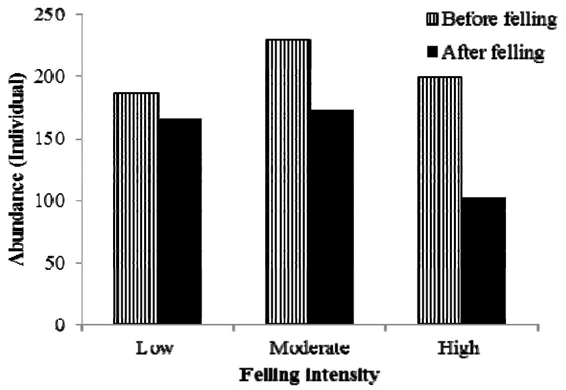

Figure 2. Abundance of hymenopteran insects before and after felling in three felling intensities

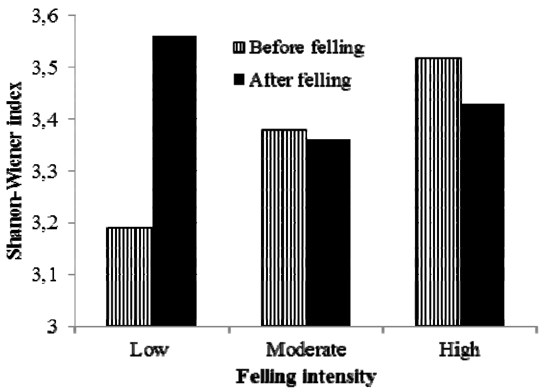

Figure 3. Diversity index of hymenopteran insects before and after felling in three felling intensities

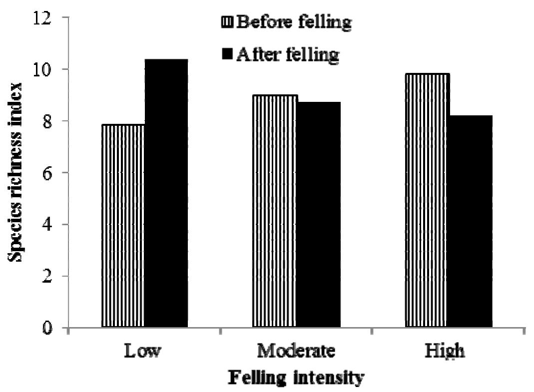

Figure 4. Species richness index of hymenopteran insects before and after felling in three felling intensities

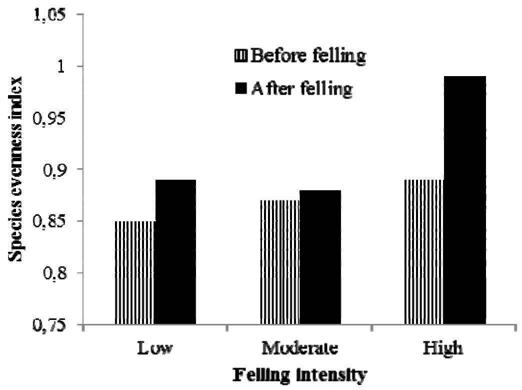

Figure 5. Evenness index of hymenopteran insects before and after felling in three felling intensities

Discussion

The results of this study indicate that tree felling had reduced the number of individual hymenopteran insects and increased the morphospecies of hymenopteran insects (Figure 2). These data suggest that the hymenopteran insects had a quick response to changes in microhabitat due to tree felling. The decline in the abundance of hymenopteran insects was greatest in high-intensity felling. It is suspected due to the migration of some insects to other new places because their original ecosystem has been disturbed by the tree felling. Although the felling intensity caused a decrease in the abundance of hymenopteran insects, the felling intensities did not significantly affect the abundance of the hymenopteran insects ($P > 0.05$) (Table 1). The results of this study are consistent with another experimental study done in Riau Province, Sumatera, showing that changes in the composition of certain vegetation in an ecosystem affect the abundance of insects (Febrita et al. 2008). Additionally, Latumahina et al. (2015) found that damage to the structure or composition of forest vegetation makes the Formicidae family (Hymenoptera) unable to have a life balance because most of the Formicidae family (Hymenoptera) utilizes forest vegetation as a source of food, nesting place, and shelter.

The Friedman test results showed that there was no difference in the composition of the species of the hymenopteran insects before and after the felling in low-intensity and moderate-intensity felling (Table 2). This means that the chance for the discovery of some number of species of hymenopteran insects, both before and after tree felling, was not much different in low-intensity and moderate-intensity felling, while in the high-intensity felling, there were significant differences in the composition of the species of the hymenopteran insects before and after the felling. It is suspected that the high-intensity felling led to the reduction of vegetation which was the nesting site and food resources for hymenopteran insects, so these insects relocated to other places to establish new nesting site and food sources. This also indicates that there were an amount of morphospecies of hymenopteran insects that were susceptible to the shrinkage of their home ranges and those that were dependent on constricted territories and resources.

The results of this study indicate that the diversity of hymenopteran insects tends to increase in the low-intensity felling and decline in the moderate-intensity and high-intensity felling (Figure 3). The species richness index of hymenopteran insects seemed to increase in the low-intensity felling and decrease in the moderate-intensity and high-intensity felling (Figure 3). The species richness index of the hymenopteran insects would decline following tree felling activities. Based on these results, it can be concluded that the reduction of felling intensities in the natural production forests can contribute to maintaining the biodiversity of hymenopteran insects. The study found that there was no dominance of the hymenopteran insects in the ecosystem of the natural production forests, which was the research site, or the entire species was at the same level of evenness (Figure 5).

Environmental factors that affect the lives of insects include temperature and humidity. Temperature gives effects on the activities, the spread, and development of insects. Humidity affects the evaporation of body fluids of insects and the selection of their suitable habitats (Aneni and Aisagbonhi 2015; Supriadi et al. 2015). Based on Pearson's correlation test, it was found that there was a close correlation between environmental factors and the abundance of hymenopteran insects (Table 4). This was presumably because of the short interval between the collection of sampling insects before and after tree felling. Field data collection was gathered two days before and after logging, so the temperature and humidity were not much different. Haneda et al. (2013) found that environmental factors (temperature and humidity) will have a visible influence on the abundance and diversity of insects if the sampling is done over a long period and in different seasons.

The relationship between temperature and the abundance of hymenopteran insects was negative (Table 4). There was a change in temperature from 30.9° C to 32.4 ° C after tree felling. Riyanto (2007) reported that the temperatures ranged from 25-32°C are the optimal temperature which is tolerant to the activities of the Formicidae family (Hymenoptera) in the tropics. Humidity and canopy cover had a unidirectional relationship with the abundance of hymenopteran insects (Table 3).

The Formicidae family was the family with the largest number of individuals in natural production forest ecosystem at the research site. The results of this study indicate that some types of the hymenopteran insects in natural production forests give different responses to changes in their habitats. Disturbance to the habitat of the hymenopteran insects through tree felling does not have the same impacts on the different types of hymenopteran insects Ewers et al. (2015) found that the contribution of invertebrates to ecosystem processes is reduced by up to one-half following logging. The abundance of some key functional groups of termites, ants, beetle, and earthworms was decreased, while for small mammals, amphibians, and insectivorous birds was increased.

This study managed to collect important information about the impacts of tree felling on the abundance of Hymenoptera in the natural production forest in East Kalimantan, Indonesia. Tree felling results in a decrease in the abundance of hymenopteran insects. A high-intensity felling results in changes to the morphospecies composition of Hymenoptera insects. Tree felling can increase and decrease the diversity of particular hymenopteran insects. High-intensity felling threatens the existence of hymenopteran insects in natural production forests. Hymenopteran insect habitat disruption in natural production forests can be reduced by minimizing the intensity of tree felling.

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