Indian Journal of Entomology Online published Ref. No. e24427 DoI. No.: 10.55446/IJE.2024.2427

DIVERSITY OF INSECTS IN *SWIETENIA MACROPHYLLA* AND *PINUS MERKUSII*

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ABSTRACT

The diversity of insects at different strata levels can provide insights into species distribution and their roles within these strata. This study aims to analyze the strata levels and insect diversity in Mahagony (*Swietenia macrophylla* King 1886) and Tusam (*Pinus merkusii* Jungh et de Vriese) stands in the Educational Forest, Maros, South Sulawesi. Data were tabulated using Microsoft Excel and analyzed for diversity, evenness, and dominance index. Further analysis will be used using XLSTAT with Principal Component Analysis (PCA) version 2021.2.2 to see the relationship between insect distribution. The research showed that *S. macrophylla* stands had higher insect diversity in the ground layer with a diversity index of 2.10, where most species found were Carpenter ant (*Camponotus* sp. Emery 1893). Meanwhile, *P. merkusii* stands have the highest diversity in the canopy layer with a diversity index of 2.47, and the most common insect found in the Thief ant (*Solenopsismolesta Say 1836*), most of which is found in the ground layer.

Key words: Biodiversity, forest, education, Indonesia, insect communities, diversity, dominance, evenness, *Camponotus* sp., *Solenopsis molesta*, vegetation

The educational forest has two large stands: Mahagony (*Swietenia macrophylla* King) and Tusam (*Pinus merkusii* Jungh. et de Vriese). An important unknown thing is how the vegetation cover interacts with the organisms within it. Insects play many roles in ecological processes, such as pollination, decomposition, and others (Crespo-Perez et al., 2020). Insects are also bioindicators of forest and environmental health (Parikh et al., 2021). Studying the diversity of insects in tree strata can show how the relationship between vegetation and other organisms can influence each other. Insect diversity can be influenced by vegetation type and environmental conditions (Zhao et al., 2023). According to Elizalde et al. (2020), insects have many roles in the sustainability of ecosystems, such as plant pollinators, decomposers, and food for other organisms. Insect diversity is key in determining health conditions and environmental changes (Chowdhury et al., 2022). Previous research revealed that insect diversity in mahogany positively correlates with humidity and vegetation cover (Campos-navarrete et al., 2015). Withaningsih et al. (2023) revealed from their research that bees, as pollinators, have a close relationship with the availability of food sources around them. This research is important as a reference for preserving forests; and will reveal how insect diversity at the strata level has a positive relationship with the existing environment. Arroyo-Rodriguez et al. (2023) explains that insect diversity is a bioindicator in determining the impact of forest damage.

Insects at the tree strata level, whether in the ground, understory, or canopy, can illustrate insect diversity, according to De Frenne et al. (2021), insect activity and habitat will adapt to environmental conditions. Knowing the distribution of insect diversity in forests is often done, but insect diversity at the strata level is still rarely done. Exploring the distribution of insects in an ecosystem will provide insight into the patterns and activities of insects in various conditions as constituents of vegetation structure (Kristensen et al., 2020). The study of the distribution of insects at the tree layer level can be vital in studying the behavior and role of insects in these layers. Analysis of insect distribution as a bioindicator for assessing forest health is important in maintaining the stability of forest ecosystems. This research is important to support the conservation and sustainability of forest ecosystems. Insect diversity is critical in explaining forest ecological management and development (Samways et al., 2020). This study identifies insect species at the tree strata level by looking at their relationship with diversity, evenness, and dominance in two stands, namely *S. macrophylla* and *P. merkusii* in the Education Forest.

MATERIALS AND METHODS

The research was carried out in October - December 2023, located in the Hasanuddin University Educational

Forest, Maros Regency. The educational forest has an area of 1,460.50 hectares (KLHK, 2020). The research points were in two stands in the educational forest, namely the stands of *S. macrophylla* (119°45'42.35"E 4°59'12.32"S) and *P. merkusii* (119°46'7.17"E 5°0'32.82"S). The two stands are each at an altitude of 418 masl. For the *S. macrophylla* stand, the *P. merkusii* stand is at an altitude of 545 masl. Sampling of insects was conducted by setting traps at various layer levels. These levels included the ground, understory, and within the canopy (nocturnal insects). Each layer had different traps: pitfall traps were used on the ground, malaise traps were used on the understory, and light traps were used in the canopy layer. An image of the research location for *Swieteni macrophylla* and *Pinus merkusii* stands can be seen in Fig. 1. Sampling of insects was conducted by setting traps at various layer levels. Each layer had different traps: pitfall traps were used on the ground (Brown and Matthews, 2016), malaise traps were used on the understory (Haris et al., 2024), and light traps were used in the canopy layer (Kammar et al., 2020). All bottles containing insect samples from each layer and location were identified and number of individuals counted. Before identification, insects were photographed using a stereo microscope (Stem 2000 with phototube camera Erc5S). Identifications were done using for Mcalpine et al. (1987), Heinrichs (1994), Borror et al. (1996), and Alfianingsih et al. (2022).

The data were tabulated in Microsoft Excel 2016, and analyzed for Shannon-Wiener diversity index, the Pielou evenness index (Odum, 1993), and the Odum dominance index 1993 at the layer level in two stands. Principal Component Analysis (PCA) was done to examine the relationships of insects in each layer, diversity, evenness and dominace insect.

RESULTS AND DISCUSSION

The most dominant order in *S. macrophylla* stands is Coleoptera, accounting for 29%, while in *P. merkusii* stands, the most dominant order is Hymenoptera, accounting for 39% (Fig. 1). The order Coleoptera, known as beetles (characterized by their hardened front wings), plays a significant role as a predator (Evans, 2023). In contrast, insects of the order Hymenoptera, such as bees and ants, are well-known for their role as parasitoids (Archibald et al., 2018). Abundant food sources and diverse microhabitats in the canopy strata influence insect diversity (Knuff et al., 2020). Insects such as flies are often found in ground strata with lots of organic material and plant remains. Species such *as Lasiusbrevicornis* and *Mydaeasetifemur* are often found in the understory layers and play an important role in the ecosystem as decomposers. Meanwhile, in the canopy layer, there are many nocturnal insects, various species of beetles, moths, and arboreal ants, such as *Componatus* sp. (Table 1). These insects are often found in the canopy to find food and protection from predators. The role of insects in forest ecosystems is significant in the food chain and in supporting broader ecosystem functions (Brockerhoff et al., 2017).

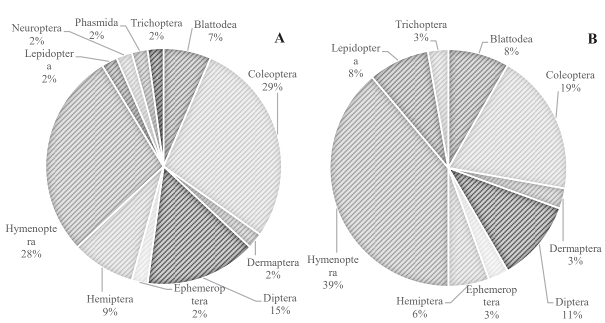

Fig. 1. Divsersity of insect orders

Principal Component Analysis (PCA) revealed on insect species' diversity, evenness, and dominance in *S. macrophylla* and *P. merkusii* stands. These showed complex distribution patterns and relationships (Fig. 2). PCA identifies several principal components explaining most data variation (Kherif and Latypova, 2020). The principal element for the *S. macrophylla* stands shows significant contributions from the diversity and evenness index values, indicating that insect species diversity is closely related to an even or stable distribution among species in this ecosystem. Additionally, the analysis tends to depict variations caused by the dominance of certain species, showing that some insect species play a dominant role in the ecosystem structure of *S. macrophylla* stands (Lelana et al., 2022). Insect

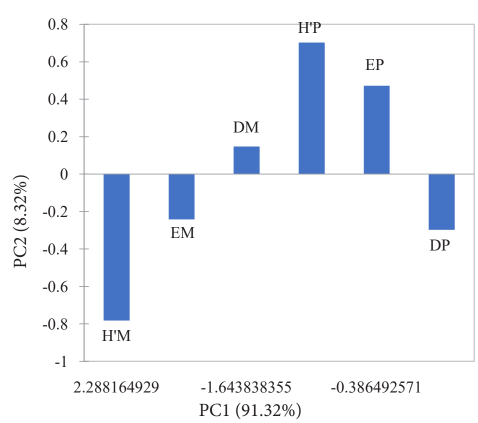

Fig. 2. The result of PCA on the diversity, evenness, and dominance of insect species in *S. macrophylla* and *P. merkusii* stands

Table 1. Insects in *S. macrophylla* and *P. merkusii* stands

Order	Family	Species	Ground		Understory		Canopy		N
			M	P	M	P	M	P	
Blattodea	Ectobiidae	*Ectobius vittiventris*		1			1		2
	Rhinotermitidae	*Reticulitermes flavipes*		1			88	1	90
		Reticulitermes Tibialis	2	4					6
Coleoptera	Tenebrionidae	*Alphitobius laevigatus*					2		2
	Anthicidae	*Macratria brunnea*					2	7	9
	Carabidae	*Anisodactylus verticalis*	4						4
		Anisodactylus nigrita		4					4
		Brachinus tenuicollis		1					1
	Chrysomelidae	*Aulacophora indica*					2		2
	Histeridae	*Merohister arboricavi*	1						1
	Laemophloeidae	*Cryptolestes turcicus*					12		12
	Latridiidae	*Melanophthalma pumila*				1	4		5
		Corticaria elongata					19	7	26
	Nitidulidae	*Glischrochilus fasciatus*					1		1
	Ptinidae	*Stegobium paniceum*					1	1	2
	Scarabaeidae	*Copris minutus*	1						1
	Staphylinidae	*Atrecus macrocephalus*					2		2
		Atheta bessobia					2	3	5
Dermaptera	Anisolabididae	*Euborellia annulipes*	2	3					5
Diptera	Fanniidae	*Fannia canicularis*			2				2
	Limoniidae	*Limonia sp.*						5	5
	Chironomidae	*Chironomus staegeri*						1	1
	Muscidae	*Hydrotaea floccosa*	2		1		5		8
		Mydaea setifemur			3	2			5
		Hydrotaea houghi			2	1			3
	Mycetophilidae	*Gnoriste macra*	1						1
	Tabanidae	*Tabanus sp.*					1		1
	Tachinidae	*Ormia punctata*			1				1
Ephemeroptera	Baetidae	*Centroptilum luteolum*					7	1	8
Hemiptera	Cicadellidae	*Aphrodes albigera*					2		2
	Cixiidae	*Cixius sp.*						3	3
	Pyrrhocoridae	*Dysdercus suturellus*					1		1
		Dysdercus cingulatus						1	1
	Rhyparochromidae	*Balboa ampliata*	6						6
		Ozophora occidentalis	6				73		79
Hymenoptera	Braconidae	*Aleiodes nolophanae*		1			3		4
		Alysia sp.						8	8
		Diachasmimorpha longicaudata	1						1
		Prenolepis imparis					63		63
		Camponotus sp.					207		207
		Lasius brevicornis	12		22				34
		Anoplolepis gracilipes	19		1				20
		Solenopsis molesta	10						10
		Solenopsis sp.					5		5
		Camponotus subbarbatus			2		27		29
		Solenopsis carolinensis					5		5
		Camponotus chromaiodes	3						3
		Odontomachus brunneus	39						39
	Formicidae	*Lasius brevicornis*		2		3			5
		Prenolepis imparis						11	11
		Camponotus sp.						19	19
		Camponotus subbarbatus						11	11
		Camponotus chromaiodes		147					147
		Anoplolepis gracilipes		140					140
		Odontomachus brunneus		19					19

(contd.)

(Table 1 contd.)

Order	Family	Species	Ground		Understory		Canopy		N
		Solenopsis sp.						6	6
		Solenopsis molesta		351					351
		Camponotus barbaricus						2	2
	Ichneumonidae	*Eremotylus subfuliginosus*			1				1
	Vespidae	*Allorhynchium argentatum*						7	7
		Polistes apachus				1			1
Lepidoptera	Hesperiidae	*Lerema accius*					3		3
	Gelechiidae	*Aroga sp.*				1			1
	Noctuidae	*Serrodes sp.*		1					1
	Lecithoceridae	*Crocanthes sp.*						1	1
Neuroptera	Chrysopidae	*Chrysopa montrouzieri*					2		2
Phasmida	Heteronemiidae	*Parabacillus sp.*	1						1
Trichoptera	Hydropsychidae	*Hydropsyche dinarica*		1			1	1	3
Total			113	710	36	9	548	99	1246
H'			2.10	1.25	1.40	1.68	2.03	2.47	
E			0.76	0.47	0.64	0.94	0.62	0.86	
D			0.19	0.36	0.41	0.21	0.21	0.11	

Note: N (number of species), M (*S. macrophylla*), P (*P. merkusii*), H' (diversity index); E (evenness index); D (dominace index)

species have their habitats and interactions with their environment to adapt (Prastiyo et al., 2024). The results showed that *S. macrophylla* stands had the highest diversity index value in the ground layer, namely 2.10. Conditions in *S. macrophylla* stands are more humid than in *P. merkusii* stands, especially in the ground layer. In *P. merkusii* stands, the highest results were obtained in the canopy layer with a diversity index of 2.47. In *S. macrophylla* stands, the highest evenness index results were obtained in the ground layer of 0.76, which is included in the stable evenness category. A stable evenness of insect species will create complex relationships for each type of insect (Cazelles et al., 2016). The *P. merkusii* stand showed the highest uniformity index value in the ground layer 0.94. The highest dominance index value in *P. merkusii* stands in the ground layer at 0.36. Insects are active in a habitat dominate in number and play an important role in the sustainability of the ecosystem (De Caceres et al., 2019). Meanwhile, in *S. macrophylla* stands, the highest dominance index value was found in the understory layer, namely 0.41.

On the other hand, the PCA results for *P. merkusii* stands show a slightly different pattern. *P. merkusii* stands are more influenced by the dominance and evenness index values, reflecting the dominance of certain species. The differing patterns produced by PCA between the two types of stands highlight how species composition and ecological interactions can vary depending on the dominant tree type and the specific environmental conditions of each stand (Baeten et al., 2019). The PCA results on the relationship between insect distribution at different layer levels in the *S. macrophylla* and *P. merkusii* stands provide deep insights into the factors influencing insect distribution patterns across various tree strata layers. PCA identifies the principal components that explain the most significant variation in the data, allowing us to see the complex relationships between diversity, evenness, and dominance. The PCA results (Fig. 3) indicate that the ground layer significantly influences the diversity distribution in *S. macrophylla* stands, where the principal component values show a strong correlation between these variables and the presence of decomposer insect species such as ants and ground beetles. In contrast, the understory and canopy layers are closely associated with diversity in *P. merkusii* stands. This analysis reveals the importance of determining insect diversity at various tree layers and highlights how interactions between biotic factors shape insect community structures within different forest stand ecosystems. By understanding these relationships, better

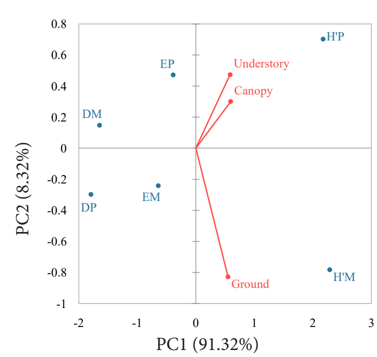

Fig. 3. PCA of the relationship between insect distribution at layer levels

conservation and forest management strategies can be designed that consider the ecological needs of diverse insect communities (Samways et al., 2020).

The dendrogram of insect species distribution clustering in *S. macrophylla* and *P. merkusii* visually depicts insect species' relationships and distribution patterns across various tree layers (Fig. 4). In this dendrogram, insect species are grouped based on similarity in their distribution and abundance in each tree layer, from the ground to the canopy. Species inhabiting the ground layer tend to cluster with other species occupying the same layer, indicating strong adaptation to environmental conditions such as high humidity and thick leaf litter. Species groups in the understory and canopy layers are more complex and widely dispersed, reflecting more significant microhabitat variation and more diverse availability of food sources at those heights. This dendrogram not only aids in understanding the community structure of insects in two different types of forest stands but also reveals the ecological factors influencing the distribution of these insect species (Schwery et al., 2023).The distribution of insects in stands of *S. macrophylla* and *P. merkusii* in the strata layers has a close relationship between interactions and insect distribution. The distribution of insect species has a positive relationship with diversity and abundance in a habitat (Swart et al., 2020). The ground layer forms a diversity closer to the diversity and evenness of insects in *S. macrophylla* stands. In contrast to *P. merkusii* stands the understory and canopy layers are closer to the diversity and evenness of *P. merkusii* stands. In the understory and canopy layers, many flying insects make the distribution of diversity and evenness closer. Diversity is higher at the top of the tree with many different kinds of insects (Traylor et al., 2022).The results of the PCA analysis illustrate that at the strata level, layers have different closeness and diversity. The distribution of insects in *S. macrophylla* and *P. merkusii* can provide an idea of the diversity of insects in each stand. Tree structure, vegetation, microclimate and environmental conditions will significantly influence species distribution in a habitat. The contribution of insect diversity is significant in determining whether ecological indicators are still maintained (Ali, 2019). The highest diversity of insects in the ground layer indicates many diverse species. The diversity of insects on the soil surface is very high, with many species and populations of ants (Razzak et al., 2022). The ideal environment and habitat and the most abundant food source for ants is on the surface of the soil from animal and plant remains (Four et al., 2019). In contrast, in the canopy layer, arboreal ants of the genus *Camponotus* and various pollinating insects play an important role in pollination, showing adaptation to different resource availability at that altitude.

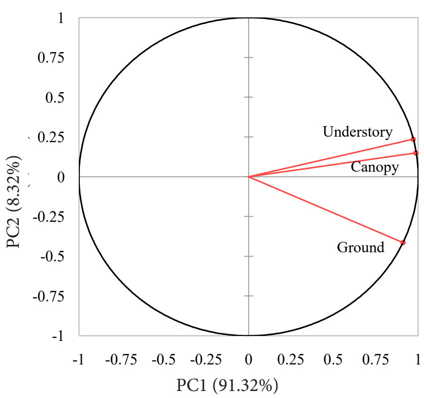

Fig. 4. Dendrogram of insect species distribution clustering

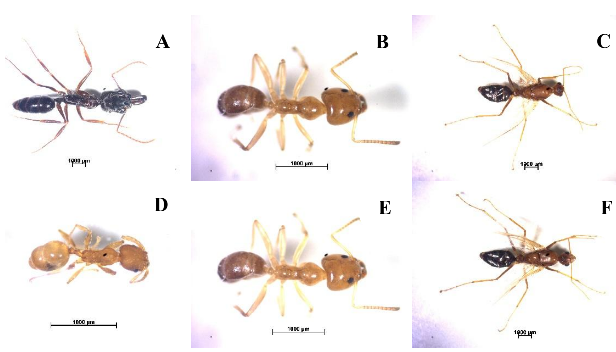

Fig. 5. Dominant insects in *S. macrophylla* stands; A. *Odontomachus brunneus*; B. *Lasiusbrevicornis*; C. *Camponotussp*. Dominant insects in *P. merkusii* stands; D. *Solenopsismolesta*; E. *Lasiusbrevicornis*; F. *Camponotus* sp.

The diversity of insects in *P. merkusii* stands highest in the canopy. In the upper layer, many species activities, such as bees, looking for food in plant flowers. Higher strata provide different habitats for moths, arboreal ants and pollinating insects (Rappa et al., 2022). The diversity of insects in various strata in these two stand types shows how interactions between tree structure, vegetation composition, and microhabitat conditions influence insect distribution and diversity so that they can support the stability and function of forest ecosystems. Insect diversity is very abundant in both stands. In the *S. macrophylla* stand, the most dominant insect species in the ground layer is *Odontomachus brunneus*, in the understory layer, the most dominant species is *Lasius brevicornis*, and in the canopy layer, the most dominant species is *Camponotus* spp (Fig. 5). *Solenopsis molesta* species are also frequently found in the lower layer as predators (Ipser and Gardner, 2020), and several *O. brunneus* species are found in the ground layer as decomposers and predators in the lower litter layer (Brandao et al., 2012). *L. brevicornis* species are frequently found as important predators in the understory layer (Campbell et al., 2018). According to Das and Das (2023), *Camponotus* spp. are significant as pollinators and predators. Every place has unique features and ecosystems that influence the insects' presence. The dominant species in the *S. macrophylla* stand is *Camponatus* sp., and the dominant species in the *P. merkusii* stand is *S. molesta*. The carpenter ant species, also called wood borers or destroyers, *Camponatus* sp., are important biological players in the ecosystem. According to Sumah and Kusumadinata (2024), *Camponatus* spp. mainly functions as a predator, while some also serve as pollinators and decomposers. Conversely, the small fire ant, or *S. molesta*, primarily serves as a predator and scavenger. One of the most ecologically successful ant species is *S. molesta*, recognized for its aggressiveness and versatility (Perfecto and Philfott, 2023). Among the many functions within their stands, both species are important predators.

ACKNOWLEDGEMENTS

Hasanuddin University and colleagues at the Faculty of Forestry are acknowledged for allowing research to be conducted in the Maros Educational Forest. Thanks also to the Educational Forest's management and friends who have assisted.

FINANCIAL SUPPORT

No funding agency has supported this work.

AUTHOR CONTRIBUTION STATEMENT

All authors contributed to the research, including the concept, research design, methods, and writing results. They have also seen, read, and approved the manuscript.

CONFLICT OF INTEREST

No conflict of interest.

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(Manuscript Received: July, 2024; Revised: August, 2024;
Accepted: August, 2024; Online Published: September, 2024)
Online First in www.entosocindia.org and indianentomology.org Ref. No. e24427