Evaluation of the ambrosia beetles traps on *Pterocarpus indicus* in Indonesia

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Abstract. *Tarno H, Setiawan Y, Rahardjo BT, Wang J. 2021. Evaluation of the ambrosia beetles traps on* Pterocarpus indicus *in Indonesia. Biodiversitas 22: 1332-1339.* Angsana, *Pterocarpus indicus* Willd., is a native tree of Southeast Asia. This tree is commonly planted in large numbers as an ornamental or shade plant along the roads, in parks, and in residential areas in Malang and Batu Cities of Indonesia. Ambrosia beetles *Euplatypus parallelus* (F.) and *Treptoplatypus micrurus* (Schedl.) have been reported to attack *P. indicus* trees in Malang and Batu Cities. Therefore, effective traps are required for early detection and monitoring of the spread of ambrosia beetles. This research aimed to evaluate the effectiveness of different traps and to investigate the diversity of ambrosia beetles on *P. indicus* trees in Malang and Batu Cities. This research was conducted along the roads in Malang and Batu Cities using four types of traps: funnel trap, window flight trap, bottle trap, and yellow sticky trap. Eleven ambrosia beetle species were collected in this research. The most abundant species were *E. parallelus* and *Cryphalus laticollis* (Browne). The funnel trap was the most effective for capturing ambrosia beetles, whereas the bottle trap was the least effective trap. The funnel trap captured more *E. parallelus* and *C. laticollis* individuals than other traps. The ambrosia beetles captured using different traps were categorized as having low diversity. The ambrosia beetles collected from Malang and Batu Cities were categorized as having moderate diversity.

Keywords: Angsana, diversity, *Euplatypus parallelus*, funnel trap, monitoring

INTRODUCTION

Angsana (*Pterocarpus indicus* Willd.) is a native tree of Southeast Asia and distributed from Southern Myanmar to the Philippines. In urban areas, *P. indicus* trees are usually planted as ornamental or shade plants along the roads, trails, parks, and settlements (Bumrungsri et al. 2008). Currently, in Malang and Batu Cities, these trees are mostly planted along the main roads as shade plants. Ambrosia beetles are the most destructive pests of woody and forestry plants worldwide (Steininger et al. 2015). The ambrosia beetles *Euplatypus parallelus* (F.) and *Treptoplatypus micrurus* (Schedl.) have been reported to attack *P. indicus* trees in Malang and Batu Cities. Symptoms of infested trees include fallen leaves and frass around holes on the bark and on the ground (Tarno et al. 2014; Tarno et al. 2015).

Ambrosia beetle infestation can decrease the *P. indicus* tree population in Malang and Batu Cities. An effective monitoring system is required to determine the population of ambrosia beetles. In addition, effective traps are required that can be used for population monitoring, predicting population outbreaks, studying population dynamics, and mass trapping to reduce the population of ambrosia beetles (Burbano et al. 2012). Several traps have been used for monitoring ambrosia beetles. Bottle traps baited with ethanol can capture 81 species of ambrosia beetles of the subfamily Scolytidae including *Xylosandrus crassiusculus* (Motschulsky) (Setiawan et al. 2018; Sittichaya and Kawin

2018). Bouget (2008) reported that a window flight trap could capture many individuals and species of ambrosia beetles of the subfamilies Scolytidae and Platypodidae. Kim et al. (2010) and Sittichaya and Kawin (2018) reported that both the funnel and yellow sticky traps were similarly effective for monitoring the population of the ambrosia beetle *Platypus koryoensis* (Murayama) and several species of ambrosia beetles of the family Scolytidae.

Because of the value of *P. indicus* trees in Malang and Batu Cities, East Java, Indonesia, the evaluation of trap types is warranted as these can be used for monitoring and mass trapping of ambrosia beetles on *P. indicus* trees in these cities. Therefore, this research aimed to evaluate the effectiveness of different traps and to investigate the diversity of ambrosia beetles on *P. indicus* trees in Malang and Batu Cities.

MATERIALS AND METHODS

Sampling protocol

The locations were determined based on a field survey along the roads in Malang and Batu Cities. Traps were installed on *P. indicus* trees that exhibited symptoms of ambrosia beetle infestation, such as fallen leaves and frass around holes on the bark and on the ground. Ambrosia beetles were collected using funnel traps, window flight traps, ethanol-baited bottle traps, and yellow sticky traps (Figure 2). Each type of trap was installed on *P. indicus*

trees in Malang City (five replications and Batu City (five replications). This research was conducted along main roads in Malang and Batu Cities from Oct to Dec 2018 (Figure 1).

Procedures

Funnel trap

This trap was made using the upper sides (funnel-like) of ten transparent bottles (volume = 1.5 L). The funnels were stacked vertically (long = 1 m) and connected using ropes. The collection bottle containing 95% ethanol (diameter = 4 cm, high = 10.5 cm) was placed at the bottom of the trap. The traps were installed on *P. indicus* trees at approximately 1.5 m above the ground (Kim et al. 2010) (Figure 2.A).

Window flight trap

The part of interception (window) (long = 20 cm × wide = 39 cm) was painted yellow, and a specimen container (long = 25 cm × wide = 20 cm × high = 9 cm) was placed at the bottom. The traps were installed on *P. indicus* trees at approximately 1.5 m above the ground (Grove 2000) (Figure 2.B).

Bottle trap

This trap was made using a transparent bottle (volume = 1.5 L) with one window cut on the side and specimen container (containing soap solution) in the bellow part. This trap was baited with 95% ethanol. About two traps were installed on one *P. indicus* tree at approximately 1.5 m above the ground (Setiawan et al. 2018) (Figure 2.C).

Yellow sticky trap

This trap was rectangular in shape (21.5 cm × 15 cm). The traps were mounted in all directions on *P. indicus* trees at approximately 1.5 m above the ground (Kim et al. 2010) (Figure 2.D).

Collection, preservation, and identification of ambrosia beetles

Samples were collected seven times in total. Samples were preserved in 95% ethanol in small tubes. The beetle specimens were placed in specimen bottles and labeled (trap type, date, and location of capture). Ambrosia beetles were identified based on morphological characters using the Olympus SZ51 stereomicroscope. The identification keys for ambrosia beetles are described elsewhere (Rabaglia et al. 2006; Wood 2007; Hulcr and Smith 2010).

Statistical analyses

The population and responses of male and female *E. parallelus* were analyzed using analysis of variance (ANOVA) ($p < 0.05$). For significant ANOVA results, means were separated using Duncan's multiple range test ($\alpha = 0.05\%$). Alpha diversity was analyzed using the Shannon–Wiener diversity index (H′), evenness index (E), and Simpson dominance index (1-D), and Beta diversity was analyzed using the Bray–Curtis (CN) similarity index (Krebs 1999; Tarno et al. 2016). All data were analyzed using R version 3.3.3 with the vegan package (Oksanen 2015; R Core Development Team 2019).
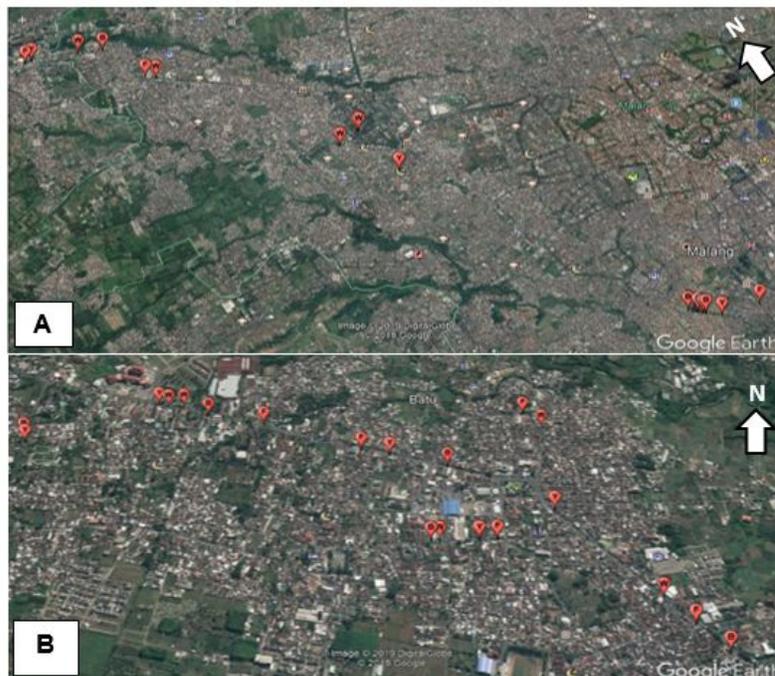
Figure 1. Map of research locations, A. Malang City (eye altitude 7,730.03 Meters and B. Batu City (eye altitude 3,168.70 Meters). Description: Red points with letters indicate the type of trap (F: Funnel trap, W: Window flight trap, B: Bottle trap, and Y: Yellow sticky trap)
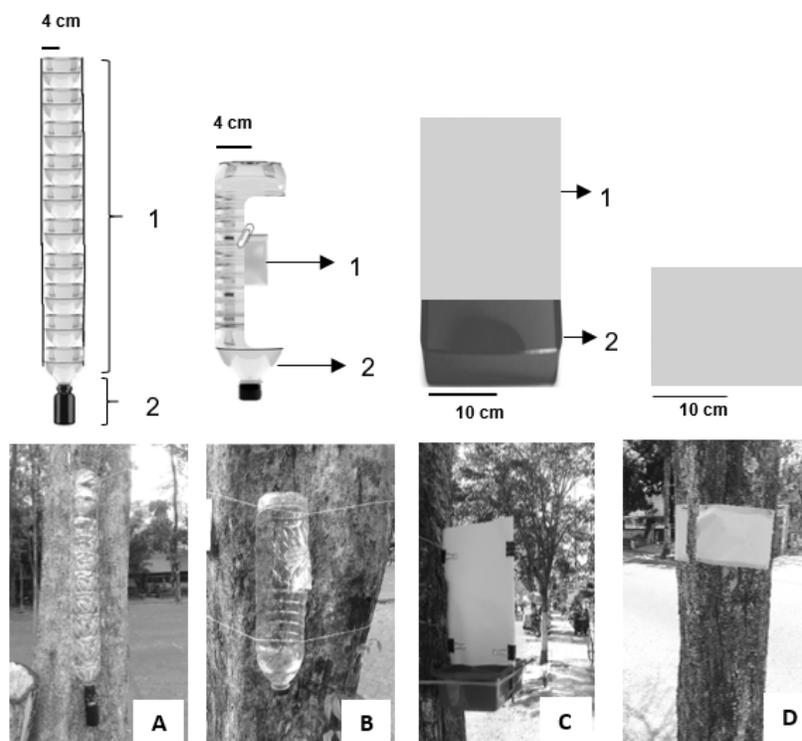
Figure 2. Types of traps used in this research. A. Funnel trap: (1) Upper sides (funnels) of 10 (l = 1 m) 1.5-L bottles connected with a rope and (2) the collection bottle containing 95% ethanol (d = 4 cm, h = 10.5 cm); B. Bottle trap: (1) A plastic bottle containing 95% ethanol as bait and (2) soap solution; C. Window flight trap: (1) the interception part painted yellow (l = 20 cm × w = 39 cm) and (2) the specimen container (l = 25 cm × w = 20 cm × h = 9 cm); and D. Yellow sticky trap (l = 21.5 cm × w = 15 cm)

RESULTS AND DISCUSSION

The population of ambrosia beetles

In Malang, a total of 17,003 ambrosia beetles were captured during sampling. Seven ambrosia beetle species were collected: *E. parallelus*, *Cryphalus laticollis*, *Euwallacea fornicatus*, *Xyleborus affinis*, *Xyleborinus exiguous*, *Hypothenemus eruditus*, and *Hypothenemus setosus* (Table 1). *Euplatypus parallelus* (65%) and *C. laticollis* (34.5%) were the most abundant species overall (Table 1 and Figure 4). The populations of *Ew. fornicates*, *Xy. affinis*, *Xyl. exiguous*, *H. eruditus*, and *H. setosus* was 0.005%, 0.328%, 0.005%, 0.093%, 0.005%, respectively. The number of captured *E. parallelus* was higher in the funnel trap (5,711). *Cryphalus laticollis* was also the most abundant species in the funnel trap (2,465). The largest number of captured ambrosia beetles was in the funnel trap ($\bar{x}$ = 234.17, SE = 46.28), which was different from that in the window flight trap, bottle trap, and yellow sticky trap in Malang City (Figure 3A). During sampling, a total of 20,324 ambrosia beetles were captured in Batu City (Table 1). There were 11 ambrosia beetle species, including *E. parallelus*, *C. laticollis*, *T. micrurus*, *Ew. fornicatus*, *Ec. spinosus*, *X. crassiusculus*, *Xy. affinis*, *Xyl. exiguous*, *H. eruditus*, *H. setosus*, and *H. dissimilis* (Table 1). The highest number of collected beetles in Batu City was for *E. parallelus* (75.06%) and *C. laticollis* (23.13%) (Table 1). The number of *T. micrurus*, *Ew. fornicatus*, *Ec. spinosus*,

X. crassiusculus, *Xy. affinis*, *Xyl. exiguous*, *H. eruditus*, *H. setosus*, and *H. dissimilis* collected was 0.009%, 0.009%, 0.009%, 0.004%, 1.544%, 0.004%, 0.172%, 0.004%, 0.044%, respectively. Overall, the number of captured ambrosia beetles was higher in the funnel trap ($\bar{x}$ = 290.48, SE = 35.28) than in the window flight trap, bottle trap, and yellow sticky trap. There was no difference in the number of captured ambrosia beetle between the window flight trap ($\bar{x}$ = 135.20, SE = 19.23) and yellow sticky trap ($\bar{x}$ = 114.08, SE = 26.12), and significantly different with the bottle trap which had the lowest number of ambrosia beetles (Figure 3.A).

In total, 37,357 ambrosia beetles were collected using different traps in this study (Table 1). There were 11 species including *E. parallelus*, *C. laticollis*, *T. micrurus*, *Ew. fornicatus*, *Ec. spinosus*, *X. crassiusculus*, *Xy. affinis*, *Xyl. exiguous*, *H. eruditus*, *H. setosus*, and *H. dissimilis* (Table 1). The number of captured beetles was higher for *E. parallelus* and *C. laticolis* overall (Table 1). *Treptoplatypus micrurus*, *Ew. fornicatus*, *Ec. spinosus*, *X. crassiusculus*, *Xy. affinis*, *Xyl. exiguous*, *H. eruditus*, *H. setosus*, and *H. dissimilis* populations were <5% overall. The number of ambrosia beetles was higher in the funnel trap ($\bar{x}$ = 262.32, SE = 29.00) than in the window flight trap, bottle trap, and yellow sticky trap. There was no difference in the number of captured ambrosia beetles between the window flight trap ($\bar{x}$ = 126.34, SE = 15.73) and the yellow sticky trap ($\bar{x}$ = 108.78, SE = 19.30) (Figure 3.B).

Table 1. Number of individuals of each species captured using the four different traps: funnel trap, window flight trap, bottle trap, and yellow sticky trap in Malang and Batu Cities, Indonesia

| Locations and species	Type of traps				Total (n)	%
	Funnel trap	Window flight trap	Bottle trap	Yellow sticky trap		
Malang City						
Euplatypus parallelus	5,711	3,000	744	1,618	11,073	65.00
Cryphalus laticollis	2,465	1,006	358	1,996	5,885	34.55
Euwallacea fornicates	-	1	-	-	1	0.005
Xyleborus affinis	10	42	1	3	56	0.328
Xyleborinus exiguous		1	-	-	1	0.005
Hypothenemus eruditus	9	2	-	5	16	0.093
Hypothenemus setosus	1	-	-	-	1	0.005
Total (individuals)	8,196	4,112	1,103	3,622	17,003	100
Batu City						
Euplatypus parallelus	7,698	3,987	1,296	2,005	15,256	75.06
Cryphalus laticollis	1,888	719	130	1,964	4,701	23.13
Treptoplatypus micrurrus	-	1	-	1	2	0.009
Euwallacea fornicates	2	-	-	-	2	0.009
Eccoptopterus spinosus	2	-	-	-	2	0.009
Xylosandrus crassiuscullus	-	-	-	1	1	0.004
Xyleborus affinis	281	22	4	7	314	1.544
Xyleborinus exiguous	-	-	1	-	1	0.004
Hypothenemus eruditus	25	3	1	6	35	0.172
Hypothenemus setosus	1	-	-	-	2	0.004
Hypothenemus dissimilis	-	-	-	9	9	0.044
Total (individuals)	10,167	4,732	1,432	3,993	20,324	100
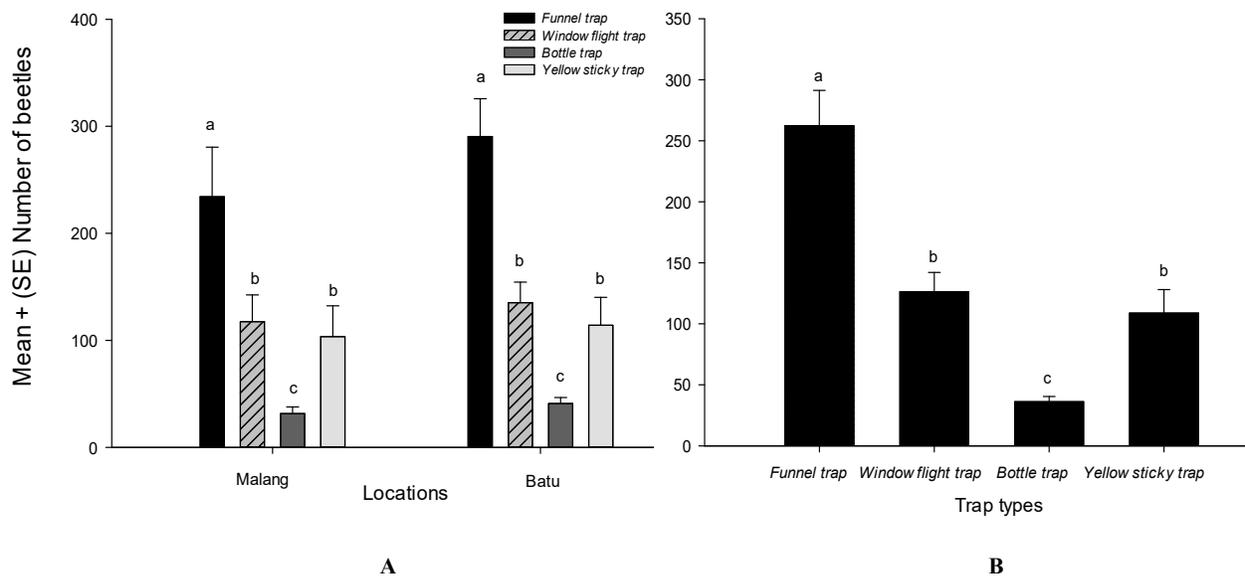
Figure 3. Mean ± (SE) number of total ambrosia beetles based on (A) Malang and Batu Cities and (B) Total accumulation. Mean values followed by the same letter are not significantly different. Duncan's multiple range test was used for the analysis between traps ($p<$ 0.05).

A   **B**

Figure 4. The most abundant species in all type of traps in Malang and Batu Cities, A. *Euplatypus parallelus* and B. *Cryphalus laticollis*

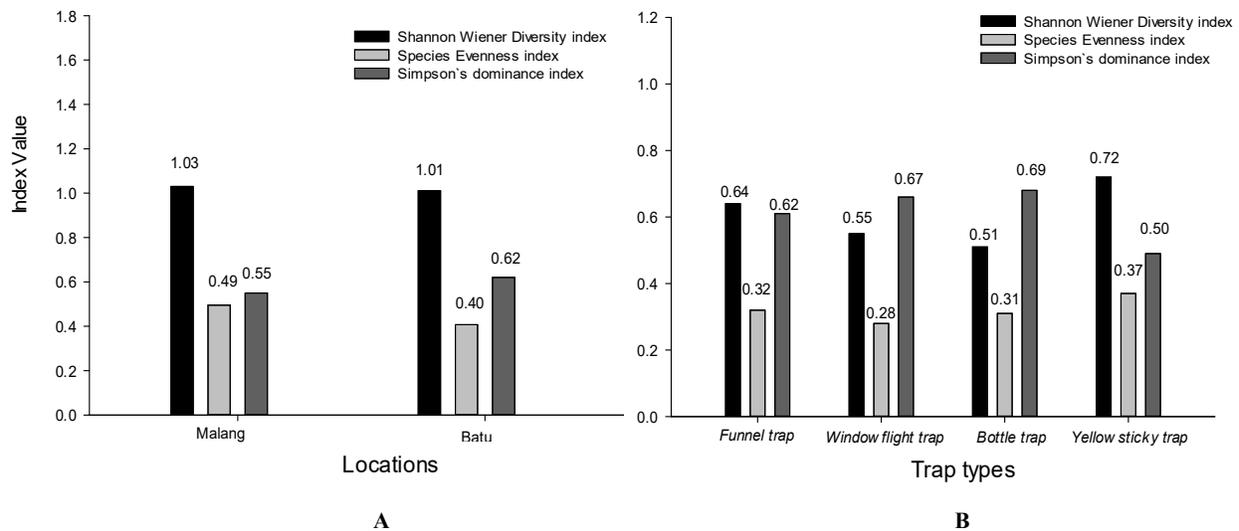**A**   **B**

Figure 5. Shannon–Weiner diversity, species evenness, and Simpson's dominance indexes for the total number of ambrosia beetles based on type of traps and locations. (a) Malang and Batu cities and (b) Type of trap. (Shannon–Weiner diversity index: <1: low level of diversity, 1–3: moderate level of diversity, >3: high level of diversity. species evenness index: $0.00 < e < 0.50$: evenness is low, $0.50 < e < 0.75$: evenness is moderate, $0.75 < e < 1.00$: evenness is high. Simpson's dominance index: $0 < d \leq 0.5$: there is no dominance of species and $0.5 > d \geq 1$: there is dominance of species).

Comparison of diversity across trap types and locations

Based on the Shannon–Wiener diversity index, there was a greater species diversity of ambrosia beetles in Malang (1.03) than in Batu (1.01) Cities, and species collected in both Malang and Batu Cities were categorized as having moderate diversity (Figure 5A). The evenness indexes for Malang City (0.49) and Batu City (0.49) indicated that these two locations have low species evenness (Figure 5A). The Simpson dominance indexes for Malang City (0.55) and Batu City (0.62) revealed that both

locations show specific species dominance (Figure 5A). The Shannon–Wiener diversity index indicated a greater species diversity of ambrosia beetles captured in the yellow sticky trap (0.721), with no differences in diversity among the funnel trap (0.640), the window flight trap (0.552), and the bottle trap (0.510) (Figure 5B). The species diversity was generally low in all types of traps. The evenness index was low for the species captured in the funnel trap (0.32), window flight trap (0.28), bottle trap (0.31), and yellow sticky trap (0.37) (Figure 5B). The Simpson dominance index for the funnel trap (0.62), window flight trap (0.67), bottle trap (0.69), while the yellow sticky trap (0.50) indicated that all types of traps have dominant species (Figure 5B). The abundance of ambrosia beetle species in Batu City (11 species) was higher than that in Malang City (Seven species). Malang City and Batu City had the same seven species i.e. *E. parallelus*, *C. laticollis*, *Ew. fornicatus*, *Xy. affinis*, *Xyl. exiguous*, *H. eruditus*, and *H. setosus*. However, four species of ambrosia beetles that were found in Batu City were not found in Malang City i.e. *T. micrurus*, *Ec. spinosus*, *X. crassiusculus*, and *H. dissimilis*.

Discussion

The ambrosia beetles collected in Malang City were dominated by *E. parallelus*, which constituted 65% of the total individuals. Six species were new records, including *C. laticollis*, *Ew. fornicatus*, *Xy. affinis*, *Xyl. exiguous*, *H. eruditus*, and *H. setosus*. *Euplatypus parallelus* was first detected in 2014 on *P. indicus* trees along the main road in Malang City (Tarno et al. 2014). This species has originated from America. It has recently invaded Southeast Asia and rapidly spread to become one of the most abundant species in Thailand (Hulcr et al. 2008). In recent years, *Euplatypus parallelus* has emerged as a pest of *P. indicus* trees in Thailand and Singapore (Sanderson et al. 1997; Bumrungsri et al. 2008). This beetle carries a pathogenic fungus and other organisms such as yeast and bacteria and can cause death and wilting of *P. indicus* trees (Tarno et al. 2016). *Cryphalus laticollis* was also found to be a dominant species, constituting 34.5% of the samples collected from Malang City. Previously, *Cryphalus* sp. was reported on and collected from *P. indicus* trees in southern Thailand (Bumrungsri et al. 2008). Some *Cryphalus* species are associated with tree pathogens such as the fungal species *Yamadazyma* sp., *Fusarium* sp., and *Penicillium pinophilum* in Madagascar, and this beetle carries the serious vascular wilt pathogen *Leptographium calophylli* that infects *Calophyllum inophyllum* L. trees (Masuya et al. 2019).

Ten species including *E. parallelus*, *C. laticollis*, *Ew. fornicatus*, *Ec. spinosus*, *X. crassiusculus*, *Xy. affinis*, *Xyl. exiguous*, *H. eruditus*, *H. setosus*, and *H. dissimilis* were documents as new records from Batu City. *Treptolatypus micrurus* represented <5% of the total beetles collected from Batu City; however, this is a native species found on *P. indicus* trees in this area. *Treptoplatypus micrurus* was the first species reported to attack *P. indicus* trees in Batu City. The infestation of these ambrosia beetles led to the death of *P. indicus* trees along the roads in Batu City

(Tarno et al. 2015). *Euplatypus parallelus* was a newly recorded and the most abundant species in Batu City in this study. This beetle species has also been reported to attack *P. indicus* trees in Malang City since in 2014, and this species may become widespread in several areas around Malang City. The high capture rate of *E. parallelus* and *C. laticollis* on *P. indicus* trees in this study indicates that both these species are now established in Malang City and Batu City.

In this study, *E. parallelus* and *C. laticollis* were captured in greater numbers in the funnel trap than in the other traps in Malang City and Batu City. The funnel trap captured more ambrosia beetles than the other traps in this study. However, the ambrosia beetles captured in this study were not attracted to the bottle trap baited with ethanol. Each trap used in this study had a different shape, color, and size. Funnel traps and bottle traps have ethanol bait to attract ambrosia beetles, but they have different forms of traps. In this study, the funnel trap was longer than the other traps and comprised a 10-unit funnel; therefore, it could capture more ambrosia beetles. Ambrosia beetles fly in response to pheromone aggregation, and these beetles perhaps hit the funnels installed on the trees and then tumbled down into the collection bottle. Funnel traps are designed as flight intercept traps for ambrosia beetles, and the beetles mostly fly into the trap, hit the underside of a funnel, and tumble down into the collection cup (Miller et al. 2018). The length of the funnel trap (number of funnels) could affect the capture of some species of saproxylic beetles (Miller and Crowe 2011). In a slash pine stand in northern Florida, the number of *Xyleborus* sp. Eichhoff (Scolytidae) captured using 16-unit funnel traps was 94% higher than that captured using 8-unit funnel traps, all baited with ethanol (Miller and Crowe 2009). Another study that evaluated the effectiveness of different traps for capturing ambrosia beetles reported that multi-funnel traps were more effective than other trap types (Flechtmann et al. 2009). Ambrosia beetles were attracted to ethanol bait in funnel and bottle traps in this study. However, funnel trap was longer than the bottle traps, so the number of ambrosia beetles trapped was less than bottle trap. Ethanol is only produced insufficiently moist sapwood and phloem tissue, it apparently signals suitable host material for ambrosia beetles and their associated fungi (Klimetzek et al. 1986). Ethanol baited traps are used in the USA to monitor the flight activity of *X. saxesenii* and *X. germanus* in horticultural tree nurseries (Miller and Rabaglia 2009). Ethanol baited funnel traps are utilized in the USA and Canada to monitor various bark and ambrosia beetles (Bullas-Appleton et al. 2014). In this study, the number of ambrosia beetles captured using the window flight trap and the yellow sticky trap showed no differences overall. The window flight trap used in this study was modified by painting the intercept part yellow such that the working principle of this trap was almost the same as that of the yellow sticky trap or color traps. Ambrosia beetles have different color and bait preferences for each species. Hanula et al. (2011) found that *Xy. glabratus* did not display a strong preference for trap color and that the responses of bark beetles to color typically varied widely.

Abbasi et al. (2008) demonstrated that green sticky traps captured more ambrosia beetles on mango trees, whereas yellow, blue, and red sticky traps were the least effective for monitoring ambrosia beetles. Strom and Goyer (2001) observed that yellow and white traps were less effective for capturing the southern pine beetle *Dendroctonus frontalis* than black, blue, brown, gray, green, or red traps. The number of ambrosia beetles captured with red and opaque traps was significantly higher than that captured with yellow or white traps (Werle et al. 2014).

The Shannon–Wiener diversity index indicated a greater species diversity of ambrosia beetles in the yellow sticky trap (0.72), with no differences in diversity between the funnel trap (0.64), the window flight trap (0.55), and the bottle trap (0.51). The species diversity of ambrosia beetles in this study was generally low in all types of traps because of the low individual distribution of each species (Tarno et al. 2016). According to Tarno et al. (2016), an index of <1 is categorized as low diversity; thus, the distribution of each species was low. The Shannon–Wiener diversity index indicated a greater species diversity of ambrosia beetles in Malang (1.030) than in Batu (1.011) Cities, and both cities were categorized as having moderate diversity. According to Tarno et al. (2016), an index of 1–3 is categorized as moderate diversity; thus, the distribution of each species was moderate. *P. indicus* trees in Malang and Batu Cities are planted as shade trees along roads, in parks, and in residential areas. Hence, the diversity of ambrosia beetle species associated with these trees was low because of the presence of only one type of plant. Multiple woody plants indirectly provide an alternate host for ambrosia beetles (Setiawan et al. 2018). Reed and Muzika (2010) stated that the abundance of ambrosia beetle species was strongly influenced by the abundance of the host.

The evenness index value for the beetle species captured in Malang City (0.49) and Batu City (0.49) indicated that these two locations have low species evenness. The evenness index for the beetle species captured using the funnel trap (0.32), window flight trap (0.28), bottle trap (0.31), and yellow sticky trap (0.37). According to Tarno et al. (2016), an index of 0.00–0.50 is categorized as low species evenness; thus, the beetle species on *P. indicus* trees is under pressure (ecosystem unstable). The Simpson dominance index for Malang City (0.55) and Batu City (0.62) revealed that both locations show specific species dominance. According to Krebs (1999), an index of >0.5 indicates species dominance.

Simpson dominance index for the funnel trap (0.62), window flight trap (0.67), bottle trap (0.69), while the yellow sticky trap (0.50) indicated that all types of traps have dominant species (Figure 6B). According to Krebs (1999), a value of >0.5 indicates species dominance and a value of 0 to ≤0.5 indicates no species dominance. In this study, the most dominant species in all types of traps in both Malang City and Batu City were *E. parallelus* and *C. laticollis*.

According to species richness, the number of different species of ambrosia beetles was higher in Batu City than in Malang City. Seven species were common among the two locations. Batu City is situated at a higher altitude than Malang City; thus, the humidity is higher and the environment is suitable for breeding in Batu City. Mean temperature and humidity greatly affect species community composition: sites with higher humidity support significantly more species living in symbiosis with fungi (ambrosia beetles) (Hulcr et al. 2008). The number of different species was higher in the funnel trap, the window flight trap, and the yellow sticky trap in all types of traps, and there were five common species each between the window flight trap and funnel trap, between the bottle trap and window flight trap, as well as between the yellow sticky trap and window flight trap. The Bray–Curtis indexes confirmed that the similarity of ambrosia beetle species between the window flight trap and the yellow sticky trap was the highest because of the similar working principle of these traps. This research was expected to provide an effective trapping method in monitoring and controlling ambrosia beetles, both in urban areas, plantations and forests.

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REFERENCES

Abbasi QD, Jan N, Mahar AN. 2008. Monitoring of ambrosia bark beetle through installation of sticky color traps at different heights in mango trees. IntlJ Fruit 7 (3): 37-41. DOI: 10.1300/J492v07n03.

Bouget C. 2008. Sampling saproxylic beetles with window flight traps: Methodological insights. Rev Écol (Terre Vie) 10: 21-32.

Bullas-Appleton E, Kimoto T, Turgeon JJ. 2014. Discovery of *Trichoferus campestris* (Coleoptera: Cerambycidae) in Ontario and first host record in North America. Can Entomol 146: 111-116. DOI: 10.4039/tce.2013.61.

Bumrungsri S, Beaver R, Phongpaichit S, Sittichaya W. 2008. The infestation by an exotic ambrosia beetle, *Euplatypus parallelus* (F.) (Coleoptera: Curculionidae: Platypodinae) of angsana trees (*Pterocarpus indicus* Willd.) in Southern Thailand. Warasan Songkhla Nakharin 30 (5): 579-582.

Burbano EG, Wright MG, Gillette NE, Mori S, Dudley N, Jones T, Kaufmann M. 2012. Efficacy of traps, lures, and repellents for *Xylosandrus compactus* (Coleoptera: Curculionidae) and other ambrosia beetles on *Coffea arabica* Plantations and *Acacia koa* nurseries in Hawaii. Environ Entomol 41 (1): 133-140. DOI: 10.1603/EN11112.

Flechtmann CAH, Ottati ALT, Berisford CW. 2009. Comparison of four trap types for ambrosia beetles (Coleoptera, Scolytidae) in Brazilian Eucalyptus Stands. J Econ Entomol 93 (6): 1701-1707. DOI: 10.1603/0022-0493-93.6.1701.

Grove SJ. 2000. Trunk window trapping: An effective technique for sampling tropical saproxylic beetles. Mem Queensl Mus 46 (1): 149-160.

Hanula JL, Ulyshe MD, Horn S. 2011. Effect of trap type, trap position, time of year, and beetle density on captures of the redbay ambrosia beetle (Coleoptera: Curculionidae: Scolytinae). J Econ Entomol 104: 501-508. DOI: 10.1603/EC10263.

Hulc J, Smith S. 2010. Xyleborini ambrosia beetles: An identification tool to the world genera. (http://itp.

lucidcentral.org/id/wbb/xyleborini/index.htm) (accessed December 2018).

Hulcr J, Beaver RA, Puranasakul W, Dole SA, Sonthichai S. 2008. A comparison of bark and ambrosia beetle communities in two forest types in Northern Thailand (Coleoptera: Curculionidae: Scolytinae and Platypodinae). Environ Entomol 37 (6): 1461-1470. DOI: 10.1603/0046-225X-37.6.1461.

Kim J, Lee J, Park I, Choi WI. 2010. Influence of trap type and location on tree trunk on *Platypus koryoensis* (Coleoptera: Platypodidae) trapping. Korean J Appl Entomol (KJAE) 49 (2): 145-149. DOI: 10.5656/KSAE.2010.49.2.145.

Klimetzek D, Kohler J, Vité JP, Kohnle U. 1986. Dosage response to ethanol mediates host selection by "secondary" bark beetles. Naturwissenschaften 73 (5): 270-271. DOI: 10.1007/BF00367783.

Krebs CJ. 1999. Ecological Methodology. Ann Surg 620. DOI: 10.1007/s007690000247.

Masuya H, Endoh R, Ando Y, Tabata M. 2019. Fungi associated with *Cryphalus rhusi* (Scolytinae: Coleoptera) infesting lacquer tree, *Toxicodendron vernicifluum*. J For Res. DOI: 10.1080/13416979.2018.1564532.

Miller DR, Crowe CM, Ginzel MD, Ranger CM, Schultz PB. 2018. Comparison of baited bottle and multiple- funnel traps for ambrosia beetles (Coleoptera : Curculionidae: Scolytinae) in Eastern United States 1. Entomol Sci 53 (3): 347-360. DOI: 10.18474/JES17-107.1.

Miller DR, Crowe CM. 2009. Length of multiple-funnel traps affects catches of some bark and wood-boring beetles in a Slash Pine Stand in Northern Florida. Fla Entomol 92 (3): 506-507. DOI: 10.1653/024.092.0315.

Miller DR, Crowe CM. 2011. Relative performance of Lindgren multiple-funnel, intercept panel, and colossus pipe traps in catching Cerambycidae and associated species in the Southeastern United States. For Entomol 104 (6): 1934-1941.

Miller DR, Rabaglia JR. 2009. Ethanol and (-)-α-pinene: Attractant kairomones for bark and ambrosia beetles in the Southeastern US. J Chem Ecol 35 (4): 435-448. DOI: 10.1007/s10886-009-9613-9.

Oksanen J. 2015. Vegan : ecological diversity. 1 (2): 1-12. DOI: 10.1029/2006JF000545.

R Core Development Team. 2019. R: A Language and Environment for Statistical Computing (Vol. 2). DOI: 10.1007/978-3-540-74686-7.

Rabaglia RJ, Dole SA, Cognato AI. 2006. Review of American Xyleborina (Coleoptera: Curculionidae: Scolytinae) occurring North of Mexico, with an illustrated key. Ann Entomol Soc Am 99 (6): 1034-1056. DOI: 10.1603/0013-8746 (2006)99[1034:roaxcc]2.0.co;2.

Reed SE, Muzika RM. 2010. The influence of forest stand and site characteristics on the composition of exotic dominated ambrosia beetle communities (Coleoptera: Curculionidae: Scolytinae). Environ Entomol 39 (McLean 1985): 1482-1491. DOI: 10.1603/en09374.

Sanderson FR, King FY, Anuar S. 1997. A fusarium wilt (*Fusarium oxysporum*) of angsana (*Pterocarpus indicus*) in Singapore: II. Natural Resistance of Angsana (*P. indicus*) to *F. oxysporum*. Arboric J 21 (3): 205-214. DOI: 10.1080/03071375.1997.9747166.

Setiawan Y, Rachmawati R, Tarno H. 2018. Diversity of ambrosia beetles (Coleoptera: Scolytidae) on teak forest in Malang District, East Java, Indonesia. Biodiversitas 19: 1791-1797. DOI: 10.13057/biodiv/d190528.

Sittichaya W, Kawin. 2018. Effect of two trap types on diversity's and population's studies of ambrosia beetles tribe xyleborini (Coleoptera: Curculionidae: Scolytinae). Songklanakarin J Plant Sci 5 (1): 62-69.

Steininger MS, Hulcr J, Šigut M, Lucky A. 2015. Simple and efficient trap for bark and ambrosia beetles (Coleoptera: Curculionidae) to facilitate invasive species monitoring and citizen involvement. J Econom Entomol 108 (3): 1115-1123. DOI: 10.1093/jee/tov014.

Strom ABL, Goyer RA. 2001. Effect of silhouette color on trap catches of *Dendroctonus frontalis* (Coleoptera : Scolytidae). Ann Entomol Soc Am 94 (6): 948-953.

Tarno H, Septia ED, Aini LQ. 2016. Microbial community associated with ambrosia beetle, *Euplatypus parallelus* on sonokembang, *Pterocarpus indicus* in Malang. Agrivita J Agric Sci 38 (81): 312-320.

Tarno H, Suprapt H, Himawan T. 2014. First record of ambrosia beetle (*Euplatypus paralellus* fabricius) infestatFon on sonokembang (*Pterocarpus indicus* Willd.) from Malang, Indonesia. Agrivita J Agric Sci 36 (2): 189-200. DOI: 10.17503/Agrivita-2014-36-2-p189-200.

Tarno H, Suprapto H, Himawan T. 2015. New record of the ambrosia beetle, *Treptoplatypus micrurus* Schedl., attack on sonokembang (*Pterocarpus indicus* Willd.) in Batu, Indonesia. Agrivita J Agric Sci 37 (3): 220-225. DOI: 10.17503/Agrivita-2015-37-3-p220-225.

Werle CT, Bray AM, Oliver JB, Blythe EK, Sampson BJ. 2014. Ambrosia beetle (Coleoptera : Curculionidae : Scolytinae) captures using colored traps in Southeast Tennessee and South Mississippi. J Entomol Sci: 49 (4).

Wood SL. 2007. Bark and ambrosia Beetles. Forest Entomology. Provo, Print and Mail Production Center, Utah, USA. DOI: 10.1002/9781444397895.ch9.