International Journal of Entomology Research
ISSN: 2455-4758; Impact Factor: RJIF 5.24
Received: 15-01-2021; Accepted: 16-02-2021; Published: 22-03-2021
www.entomologyjournals.com
Volume 6; Issue 2; 2021; Page No. 109-115

A rapid assessment of insect communities in Balsa plantations of East New Britain Province, Papua New Guinea

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Abstract
Insect communities were documented across six (6) commercial Balsa plantations in East New Britain Province of Papua New Guinea. Gilalum recorded mostly Coleopterans (50%) while very few Hymenopterans (16.7%), Lepidopterans (16.7%), Orthopterans (16.7%) and Odonata (16.7%). Lepidopterans were common in Kaingaski (55.6%) when compared to other taxa. There were more lepidopterans (58.8%) in Klinwata plantation than other taxa while 23.5% consisted of Orthopterans. Laup plantation had 35.7% lepidopterans, 21.4% hymenopterans, 21.4% odonatans, 14.3% coleopterans and 7.1% orthopterans. Putput had a good representation of lepidopterans (56.2%) followed by coleopterans (28.1%) and orthopterans (9.4%). Putput plantation was the most diverse site having a total of 32 species which were uniformly distributed (H=2.66, E=0.77). Tanao had the second highest diversity with species richness of 19 which were evenly distributed within the site (H=2.37, E=0.81). Laup plantation had the third highest diversity of 14 species with uniform distribution (H=1.93, E=0.73). Klinwata followed with total of 17 species that were less uniform in their distribution within the plantation (H=1.72, E=0.61). Gilalum recorded 6 species that were not uniformly distributed within the plantation (H=0.93, E=0.52). Kaingaski plantation had the lowest diversity with 9 species that were poorly distributed within the study site (H=0.79, E=0.36). From the aforementioned results, we concluded that a plantation with vegetation heterogeneity, complex undergrowth, low anthropogenic disturbances, long-standing trees, strict conservation guidelines and effective monitoring is paramount to enhance species richness of insects.

Keywords: insect communities, balsa plantations, diversity, species richness, monitoring

Introduction

The diversity and general distribution of insects in commercial Balsa (*Ochroma pyramidale* Cav.*)* plantations of East New Britain province is currently unknown. The impacts of large-scale commercial balsa plantations on insect diversity are not well documented in Papua New Guinea (PNG). Rapid clearing of tropical forests to meet rising demands for food and biofuels has led to decline in biodiversity and increase carbon emissions (Koh *et al*. 2011; Beiroz *et al*. 2017) [19, 4]. Plantation forests have been reported to host lower diversity of bioindicators such as invertebrates, birds, mammals and vascular plants (Stephens & Wagner 2007) [33]. In order to maintain a balance between plantation forests and wildlife, managers of plantations are urged to promote landscape heterogeneity to enhance the conservation of biodiversity (Kanowski *et al*. 2005) [18]. Insects are cosmopolitan and their presence or absence can be used as bioindicators to measure forest health (Stephens & Wagner 2006; Akutsu *et al*. 2007) [32, 1].

Insects can be categorized according to their feeding guilds and the type of habitat they are found in. The main feeding guilds of insects are; folivore (leaf-feeders), granivore (seed-feeders), frugivore (fruit-feeders), xylophagy (wood-feeders), mycetophagy (fungi-feeders), coprophagy (dung-feeders), and necrophagy (flesh-feeders) (Novotny & Basset 2005) [26]. Most of the studies were restricted to folivores particularly caterpillars and there is need to study other feeding guilds (Novotny & Basset 2005; Lewinsohn & Roslin 2008) [26, 23]. Common folivorous beetles (Coleoptera) are from the families Chrysomelidae, Coccinellidae, Scarabaeidae and Aderidae. The samples on larval leaf chewers (folivores) were dominated by Lepidoptera, while Hymenoptera were very rare (Novotny *et al*. 2010) [27]. Predominant Lepidopteran folivores in PNG are from the families of Geometridae, Noctuidae, Crambidae, Tortricidae and Lymantriidae (Novotny *et al*. 2002) [28]. Another important order of insects are Ants (Hymenoptera) which are also used as indicator species in diversity studies. Ants are attracted to the foliar nectaries of juvenile *O. pyramidale* and act as antiherbivore agents on Ochroma (O'Dowd 1979) [29].

The impact of large-scale plantations such as balsa on biodiversity decline has not been entirely quantified (Koh *et al*. 2011) [19]. Intensive agricultural farming inevitably causes biodiversity declines; however, conservation biologists are not persuaded enough if similar conservation scenario can be observed in a more complex and structural planted forest systems like balsa (Dunn 2004; Wright & Muller-Landau 2006; Gardner *et al*. 2007; Laurance 2007) [11, 37, 14, 22]. A study done on diversity among bark beetle (Coleoptera: Curculionidae: Scolytinae) species within different forest plantations in Ecuador shows that balsa had the highest Shannon-Wiener diversity index (Chévez *et al*. 2017) [8]. *O. pyramidale* is a host to xyleborine ambrosia beetle (*Coptoborus ochromactonus* Smith & Cognato) which is considered as pest (Castro *et al*. 2019) [6]. We hypothesized that balsa plantations providing diverse resources (refugia, food, oviposition sites) with less anthropogenic disturbances will attract more insect species.

Materials and methods

(a) Study Sites

The sampling of insects was done in six (6) commercial balsa plantations within East New Britain province which are managed by 3A Composites Pty Ltd (fig. 1). Klinwata plantation (-4º 20′ 10.58 ″ S, 151º 53′ 26.50″ E) has a total planted area of 238.27ha. It is comprised of Balsa trees that have been planted in 2009, 2011, 2012, 2017, 2018 and 2019. Sampling of insects was done using flight-intercept trap, sweep net, ant tuna bai, light trap and hand collection. Flight-intercept traps, tuna baits and light traps were placed in 2012 planted sites while sweep netting and hand collection were done randomly within the plantation. Presence of cleared areas are visible at Klinwata due to extensive harvesting of balsa recently whereas extensive gardening was predominant in the southern portion. To the west is Kaingaski plantation (-4º 22′ 41.81 ″ S, 151º 46′ 55.84″ E) which is surrounded by customary lands. The planted area covers 20.028ha comprising of balsa trees that were planted in 2018. Excluding the planted area, less than 8ha of the plantation has been harvested. Although there is a thin strip of buffer forest running along the plantation edge from east to south-west, there is evidence of land loss which are considered unsuitable for replanting due to its steepness (>450º). Flight-intercept trap, lights trap and tuna baits were placed within the plantation while hand collection and sweep netting were done randomly. Gilalum plantation (-4º 26′ 21.57 ″ S, 152º 18′ 31.58″ E) has a total planted area of 30.99ha and consist of balsa trees that have been planted in 2012, 2013 and 2019. Although there are notable High Conservation Value (HCV) sites such as waterfall and roosting cave of the spurred horseshoe-bats (*Hipposoderos calcaratus*), most of the balsa forests have been cleared. There are also significant land losses that are deem unsuitable for replanting. Most of the cleared sites were substituted for gardening by the locals. Laup plantation (-4º 27′ 56.44 ″ S, 152º 10′ 09.97″ E) has a total planted area of 81.28ha with buffer zones running along Laup stream. Presence of land losses and harvested sites are also evident along the stream and adjacent gullies. Sampling of insects was done randomly within the forest plantation and along the stream. The balsa trees at Tanao plantation (-4º 17′ 05.81 ″ S, 152º 05′ 07.44″ E) were all planted in 2018 in a total land area of 18.81ha. There are presence of HCV sites consisting of Japanese tunnels, caves and buffer forest. Light trapping, flight-intercept and tuna baits were executed within the plantation while sweep netting and hand collection was done randomly within buffer zones as well as within plantation. The largest plantation was Putput (-4º 32′ 45.70 ″ S, 152º 19′ 28.56″ E) with a total planted area of 589.35ha. Putput also has a large buffer forest to the south of the plantation that provides refugia for fauna species such as birds, bats and small mammals.

Fig 1: Insects were sampled in six (6) sites within East New Britain Province. The study sites are commercial Balsa plantations owned by 3A Composite Pty Ltd. The sampling sites are situated more than 10km apart on ground distance.

Insect sampling

The field sampling was carried out from 6th to 24th January 2020. All sites were carefully studied using maps provided by 3A Composites prior to sampling survey. The field assessment included both site inspections and detailed insect assessment of sample sites. Insect sampling was done using five (5) sampling techniques: passive sampling (flight-intercept trap, light trap & tuna bait) and direct sampling (sweep net & hand collection). Flight-intercept trap, light trap and tuna baits were done within the balsa plantations while sweep netting and hand collection was executed randomly in plantation as well as buffer zones. The sampling was irregular, as it included insects on any balsa trees, other woody trees, shrubs or weeds encountered during the sampling walk within each respective plantation. This allowed for comparison between plantations that has buffer and/or less buffer zones. Anthropogenic disturbances such as clear-fell harvesting and gardening was also a considered a factor in quantifying insect communities. The age of balsa trees, diversity of undergrowth vegetations and undergrowth architectural structure can also influence the diversity of insect communities. Sweep netting and hand collection was done randomly during the regular field patrol in both balsa plantations and buffer zones. These active sampling techniques were used mainly to collect mobile insects such as butterflies (Lepidoptera), beetles (Coleoptera), dragonflies (Odonata) and crickets (Orthoptera). Moths (Lepidoptera) on the other hand, was sampled using light traps and to a lesser extent beetle (Coleoptera. i.e., *Pteroptyx effulgens* O.). This qualitative presentation is relevant to provide a bird's eye-view of distribution of insects in a single episode sampling. All insect specimens were identified to Family and then into morpho-species based on similar morphological features. Each morpho-species was given a special identification code comprised of first three letter of the Order followed by a dash and three digits (i.e., LEP-XXX).

(c) Data analysis

Analysis was focused on higher taxa, Family and Order while species data was solely used for quantifying diversity since it was very low. We calculated the species diversity using Shannon-Wiener index (H) as well as species evenness (Pielou's index, E) for each study site (Iamba *et al*. 2018) [15]. All the data analysis and graphing were done in RStudio (version 4.0.3). The ecological package, vegan, was used in calculating the diversity and species evenness. Graphs relating to species richness, distribution and composition were constructed with ggplot2 package. The data set consists of counts of species, Family, Order and abundance within six (6) sampling sites. The data set was analyzed using Generalized linear model (glm) due to its non-normal distribution as tested by Shapiro-Wilk test in dplyr package ($p<0.05$). We fitted glm to species, Family, Order and abundance data using a Poisson exponential family with the log link function (Royer *et al*. 2020). Separation of means of each sampling sites by Tukey Honest Significant Difference test (Tukey HSD) was executed in agricolae package using *HSD.test* function. Cross-site analyses were preferred even when there was insufficient data at one site.

Results

A total of 67 species, 23 Families and 5 Orders of insects were sampled during the rapid survey. The composition of insect Orders, Families and species varied among sampling sites (table 1.). Gilalum recorded mostly Coleopterans (50%) while very few Hymenopterans (16.7%), Lepidopterans (16.7%), Orthopterans (16.7%) and Odonata (16.7%). The Guinea firefly, *Pteroptyx effulgens* (Lampyridae) was a common coleopteran species in Gilalum. Lepidopterans were common in Kaingaski (55.6%) when compared to other taxa. Waterlogged area along plantation edge also provided a habitat for two dragonfly species, *Agrionoptera insignis* and *Neurothemis terminata* (Libellulidae). There were more lepidopterans (58.8%) in Klinwata plantation than other taxa while 23.5% consisted of Orthopterans. Species from Gryllidae and Acrididae were common orthopterans found in Klinwata. Laup plantation had 35.7% lepidopterans, 21.4% hymenopterans, 21.4% odonatans, 14.3% coleopterans and 7.1% orthopterans. The Laup stream provided a suitable habitat for three damselfly species; *Rhinocypha liberate*, *Rhinocypha frontalis* and *Nososticta Africana*. Putput had a good representation of lepidopterans (56.2%) followed by coleopterans (28.1%) and orthopterans (9.4%). Light trapping in Putput plantation caught species from Crambidae, Noctuidae, Blastobasidae, Erebidae, Sphingidae, Papilionidae and Lycaenidae. Notable species were *Glyphodes bivitralis* (Crambidae), *Blastobasis* sp. (Blastobasidae), *Balsa tristrigella* (Noctuidae), *Graphium thule* (Papilionidae) and *Catopyrops ancyra* (Lycaenidae). Tanao plantation had more coleopterans (38.1%) compared to other five sites. Common coleopteran species include; *Oribius destructor* (Curculionidae), *Alcidodes elegans* (Curculionidae), *Pteroptyx effulgens* (Lampyridae) and *Callistochroma flavofasiata* (Cerambycidae).

Table 1: Sampling of five (5) insect Orders (higher taxa) were done in all six (6) Balsa plantations. Due to irregularity of sampling, the frequency (N) differed within each site. The frequency of each Order is shown outside the brackets while percentage composition within the brackets. The mean, standard deviation (SD), median, minimum and maximum counts of abundance are also displayed for each site.

	Gilalum [1](N=6)	Kaingaski [1](N=9)	Klinwata [1](N=17)	Laup [1](N=14)	Putput [1](N=32)	Tanao [1](N=21)
Order						
[2]Coleoptera	3 (50.0%)	1(11.1%)	2 (11.8%)	2 (14.3%)	9 (28.1%)	8 (38.1%)
[2]Hymenoptera	1(16.7%)	1(11.1%)	1(5.9%)	3 (21.4%)	2 (6.2%)	2 (9.5%)
[2]kepidoptera	1 (16.7%)	5 (55.6%)	10 (58.8%)	5 (35.7%)	18 (56.2%)	7 (33.3%)
[2]Orthoptera	1 (16.7%)	0 (0%)	4 (23.5%)	1(7.1%)	3 (9.4%)	4 (19.0%)
[2]Odonata	0 (0%)	2 (22.2%)	O (0%)	3 (21.4%)	0 (OM	0 (0%)
Abundance						
[3]Mean (50)	9.50 (16.1)[a]	5.33 (13.0)[abc]	3.29 (7.74)[cd]	6.36 (9.11)[ab]	2.25 (4.44)[d]	3.76 (5.25)[bcd]
Median	3.50	1.00	1.00	2.00	1.00	2.00
(Min, Max)	[1.00, 42.0]	[1.00,40.0]	[1.03, 33.0]	[1.00,30.01]	[1.00,23.01]	[1.00, 21.0]

[1]Sampling frequency.

[2]Insect Order showing number of species outside the bradiet and percentage (%) inside the bracket.

[3]Means sharing the same letter are not statistically significant at 4.05.

Statistics was performed at Family and Order taxa along with abundance. The mean±SD of each variable varied on certain degree between sampling sites (table 2.). There was homogeneity between Laup (9.8 ± 4.7, p>0.05) and Tanao (9.9 ± 5.3, p>0.05) on family taxon. Family homogeneity was also observed in Kaingaski (12 ± 5.2, p>0.05), Klinwata (12 ± 6.1) and Putput (11 ± 6.3, p>0.05). Gilalum had low family composition compared to other study sites (11 ± 3.3, p<0.05). No difference existed between Orders since all five taxa were sampled at all study sites.

Table 2: The three (3) variables; Family and Order (higher taxa), and abundance were quantified for each of the six (6) Balsa plantations. The mean and standard deviation (mean±SD) for each variable is displayed for individual site.

	Gilalum [1](N=6)	**Kaingaski [1](N=9)**	**Klinwata [1](N=17)**	**Laup [1](N=14)**	**Putput [1](N=32)**	**Tanao [1](N=21)**
Family						
[2]Mean± SD	11 ± 3.3ab	12 ± 5.2a	12 ± 6.1a	9.8 ± 4.7b	11 ± 6.3a	9.9. ± 5.3b
Order						
[2]Meant ± SD	2.2 ± 1.6a	2.9 ± 0.93a	3.2 ± 1.2a	2.9 ± 12a	2.6 ± 1.2a	2.5 ± 1.5a
Abundance						
[2]Mean ± SD	9.5 ± 16a	53 ± 13abc	3.3 ± 7.7cd	6.4 ± 9.1ab	2.3 ± 4.4d	3.8 ± 5.3bcd

[1]Sampling frequency.
[2]Means sharing the same letter are not statistically significant at a4.05.

There was no significant difference among the mean number of families in the study sites (Fig. 2). Kaingaski (12 ± 1.75, p>0.05) had the highest number of insect families however it was not statistically significant. Gilalum (10 ± 3.27, p>0.05), Laup (10 ± 1.26, p>0.05) and Tanao (10 ± 1.16) showed homogeneity in family composition. For sampling methods, sweep net caught the highest number of insect families (13 ± 1.15, p<0.05). Ant bait (11 ± 0.00, p>0.05), flight-intercept (11 ± 1.23, p>0.05) and light trap (11 ± 0.89, p>0.05), all caught similar family composition. The lowest family composition was recorded in hand collection method (8 ± 1.24, p<0.05). All means were separated using Tukey HSD test and those sharing the same letter were deem not significant at α=0.05.

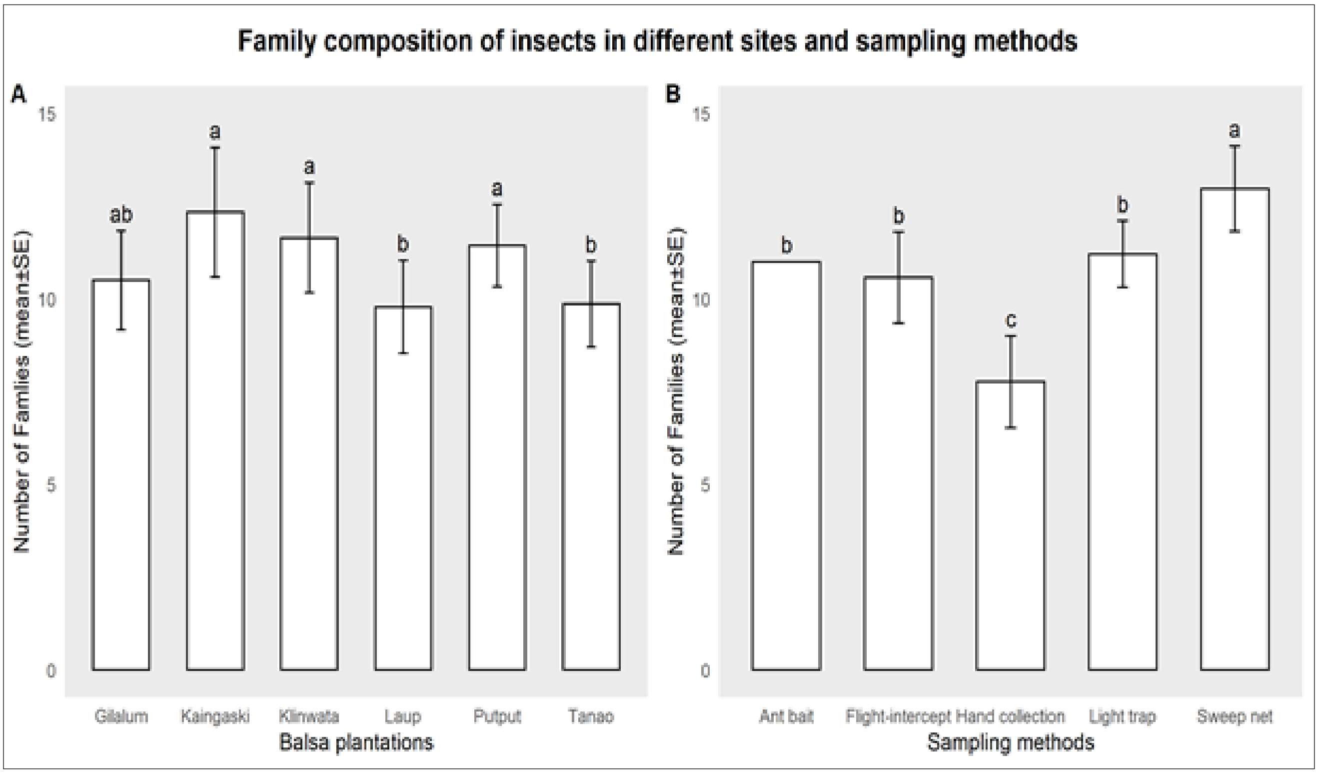

Fig 2: The Family composition of insects differs to some degree between study sites and sampling methods. (A) Kaingaski had the highest number of families (12 ± 1.75, p>0.05) but was not statistically significant. Gilalum (10 ± 3.27, p>0.05), Laup (10 ± 1.26, p>0.05) and Tanao (10 ± 1.16) had family composition. (B) Sweep net caught the highest number of insect families (13 ± 1.15, p<0.05) while ant bait (11 ± 0.00, p>0.05), flight-intercept (11 ± 1.23, p>0.05) and light trap (11 ± 0.89, p>0.05) had similar family composition. Hand collection method recorded the lowest family composition (8 ± 1.24, p<0.05). Means sharing the same letter are not significantly significant at α=0.05.

The abundance was distinct amongst study sites as shown by significant mean±SD values (table 2.). Gilalum plantation had the highest mean abundance (9.5 ± 16, p<0.05) while the lowest abundance was recorded in Putput plantation (2.3 ± 4.4, p<0.05) (Fig. 3). Kaingaski (5 ± 4.33, p>0.05), Klinwata (3 ± 1.88, p>0.05), Laup (6 ± 2.44, p>0.05) and Tanao (4 ± 1.14, p>0.05) did not differ significantly from each other (p>0.05). Although ant bait did not catch a significant family composition, it had the highest number of individuals (27 ± 3.79, p<0.05). Flight-intercept trap recorded the second highest abundance yet in contrary, it was less than family composition (7 ± 2.91, p<0.05). Sweep net, light trap and hand collection methods recorded non-significant low abundances (p>0.05).

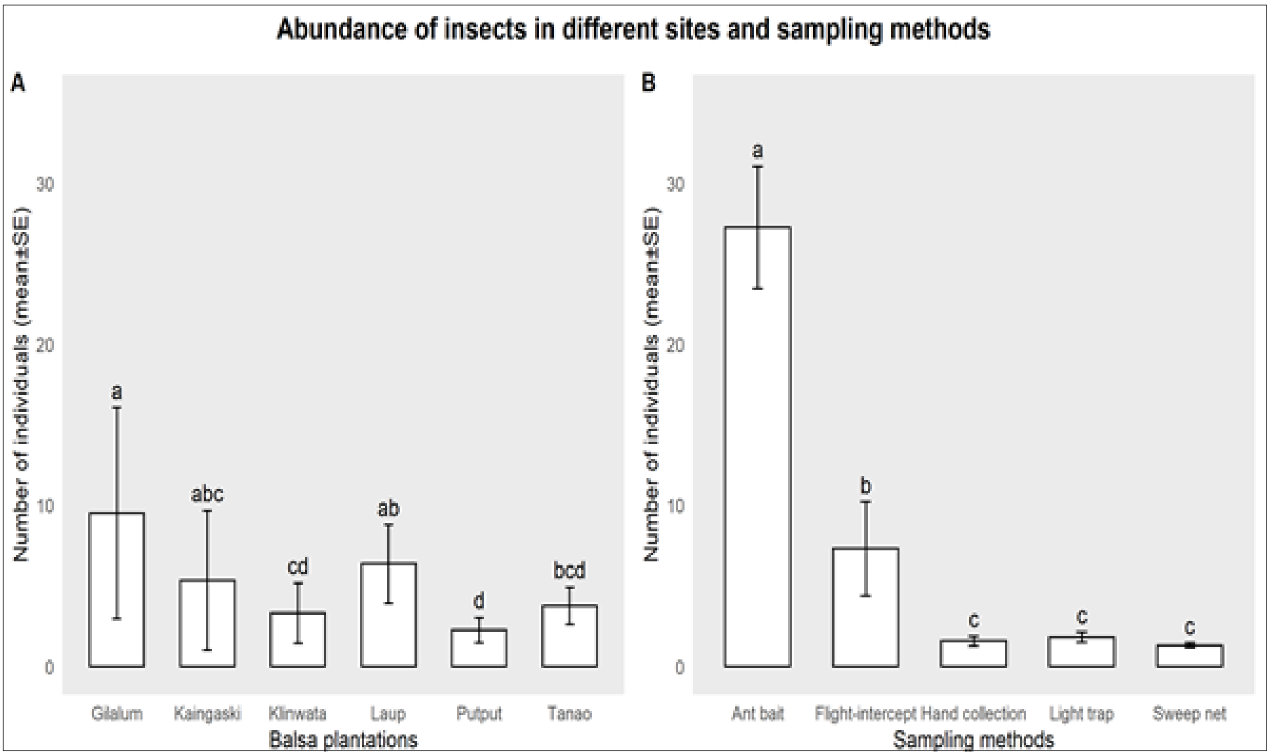

Fig 3: Insect abundance showed distinct results in both study sites and sampling methods. (A) The number of individuals reached the highest in Gilalum (16 ± 6.56, $p<0.05$) while Putput recorded the lowest abundance (2± 0.78, $p<0.05$). The abundance of the other four sites did not differ significantly from each other ($p>0.05$). (B) Ant bait caught the highest number of individuals (27 ± 3.79, $p<0.05$) while sweep net, light trap and hand collection recorded lower abundance ($p>0.05$). Flight-intercept had the second highest abundance although it was almost four times less than ant bait ($p<0.05$).

The species diversity and evenness also varied across the study sites. Putput plantation was the most diverse site having a total of 32 species which were uniformly distributed (H=2.66, E=0.77). Tanao had the second highest diversity with species richness of 19 which were evenly distributed within the site (H=2.37, E=0.81). Laup plantation had the third highest diversity of 14 species with uniform distribution (H=1.93, E=0.73). Klinwata followed with total of 17 species that were less uniform in their distribution within the plantation (H=1.72, E=0.61). Gilalum recorded 6 species that were not uniformly distributed within the plantation (H=0.93, E=0.52). Kaingaski plantation had the lowest diversity with 9 species that were poorly distributed within the study site (H=0.79, E=0.36). Both Gilalum and Kaingaski were categorized as plantations of low species diversity. Generally, a site is considered more diverse when the diversity (H) index value is bigger whereas Pielou's evenness (E) is interpreted from 0 (no evenness) to 1 (complete evenness). The study sites having bigger diversity (H) indexes and smaller evenness (E) values were interpreted as more diverse.

Discussion
The distribution of insect communities across the study sites showed some degree of heterogeneity. Since all sites are commercial balsa plantations, they are all succumb to anthropogenic disturbances and some form of environmental degradation. Rapid clearing of tropical forests to meet rising demands for food and biofuels has led to decline in biodiversity and carbon emissions (Koh *et al*. 2011; Beiroz *et al*. 2017) [19, 4]. Plantation forests have been reported to host lower diversity of bio indicators such as invertebrates, birds, mammals and vascular plants (Stephens & Wagner 2007) [33]. This low-species trajectory was evident in Gilalum and Kaingaski plantations where environmental disturbances such as recent harvesting, planting, oil palm development and gardening were common. In order to maintain species diversity, there is a need to promote landscape heterogeneity that can enhance conservation of insect biodiversity (Kanowski *et al*. 2005) [18]. Landscape heterogeneity in plantation systems should be focused on buffer zones and the effort to restore rainforest patches and corridors (Erskine 2002; Catterall *et al*. 2004) [13, 7]. According to Edwards *et al*. (2012) [12], forest patches or buffer zones can host higher biodiversity by providing survival niches hence they should be protected. There were lack of buffer zones and forest patches within Gilalum and Kaingaski plantations. Narrower buffer patches within the contiguous balsa plantation at Kaingaski may have contributed to the presence of similar species, therefore wider buffer zones are recommended to boost diversity (Erskine 2002; Catterall *et al*. 2004) [13, 7]. Putput plantation had sufficient areas of natural buffer forests, and most of the balsa trees were more than 9 years old with well-developed branches and rich undergrowth vegetations. The height, canopy structure, architecture and age of vegetation can affect the refugium of insects (Iamba & Yoba 2020) [15]. Therefore, Putput recorded the highest species diversity of insects compared to other sites. Our study supports Beck *et al*. (2002) that long standing planted forests with a rich undergrowth of plant richness supports a diverse moth.

Community. Putput and Tanao had high diversity of insect communities due to their long-standing planted trees and complex undergrowth vegetation (Chey *et al*. 1997; Beck *et al*. 2002) [9, 3]. Tanao plantation which had the second highest diversity also had a unique buffer zone with heterogenous host plants like ferns (*Sphaerostephanos unitus),* gorgor (*Hornstedtia lycostoma),* Giant taro

(Alocasia macrorrhizos) and sub-woody vine (*Merremia peltata*). Laup had the third highest diversity which can be related to the stream flowing through the plantation providing a niche for aquatic species (Irwin *et al*. 2010) [17]. The stream provided a suitable habitat for three damselfly species; *Rhinocypha liberate*, *Rhinocypha frontalis* and *Nososticta Africana*. Insects such as dragonflies and damselflies have a narrow distribution and can be less persistent than species with a broad distribution (Korkeamäki & Suhonen 2002; Irwin *et al*. 2010) [20, 17]. Odonata species can serve as bioindicator for biodiversity conservation since they represent wetlands of importance (Noss 1990; Lambeck 1997) [25, 21]. Anthropogenic disturbances to stream habitat can affect the developing larvae of Odonatans by amending the ambient aquatic conditions and adults thereby lose their hunting habitat (Sweeney 1993; Luke *et al*. 2017) [35, 24]. Klinwata plantation had less species than Laup although there is presence of some buffer forests. High anthropogenic disturbances such as rapid harvesting with use of heavy machineries and extensive gardening in cleared areas might have lowered the species richness (Ryszkowski *et al*. 2001; Dunn 2004; Wright & Muller-Landau 2006; Gardner *et al*. 2007; Laurance 2007) [31, 11, 37, 14, 22]. The Hymenopteran species such as *Wasmannia auropunctata*, *Anoplolepis gracilipes*, *Anochetus chirichinii*, *Dolichoderus thoracicus* and *Euprenolepis* sp. were abundant across most study sites. Ants were more abundant in balsa plantations because they are frequent feeders of foliar nectaries in juvenile balsa (Ochroma pyramidale) (O'Dowd 1979) [29]. Foliar and extrafloral nectar of O. pyramidal provides food resource for most ants and other insect species (Carroll & Janzen 1973) [5]. Arthropods such as insects are highly dynamic, and are sensitive to habitat disturbance (Underwood & Fisher 2006; Stewart *et al*. 2007) [36, 34]. Insects (i.e., ants) have restricted habitats and small population ranges thus, small buffer patches would contain unique species (Irwin *et al*. 2010). Deforestation and forest disturbance are likely to drive ants, flies and butterflies to extinction (Allnutt *et al*. 2008) [2].

Conclusion

For the aforementioned sites, we recommend a proper conservation management especially within areas of high anthropogenic disturbance (Daily 2001) [10]. Therefore, for future biodiversity survey, we would suggest assessors to focus on the three focal taxa: Coleopterans, Hymenopterans and Lepidopterans. Special focus is needed for Odonata species which can serve as bioindicator in biodiversity conservation and represent importance of wetlands (Noss 1990; Lambeck 1997) [25, 21]. In order to maintain high species diversity, a more complex and structural planted forest systems along with sufficient buffer forests would be recommended (Dunn 2004; Wright & Muller‐Landau 2006; Gardner *et al*. 2007; Laurance 2007) [11, 37, 14, 22]. A plantation with vegetation heterogeneity, complex undergrowth, low anthropogenic disturbances, long-standing trees, strict conservation guidelines and effective monitoring will enhance species richness of insects.

Acknowledgments

This study was part of a rapid High Conservation Value (HCV) assessment of Balsa plantations within East New Britain Province. We are grateful for the support of 3A Composite staffs namely Dwayne Peter, and Harlan Kuvi for the field support. Special thankyou to the FSC Coordinator, Dr Sabine Hess, for organizing, planning, and overseeing the rapid assessment survey. Our extended appreciation to 3A Composites PNG for providing an opportunity to understand FSC standards.

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