# Community composition and species diversity of fruit-eating-insects of *Gymnacranthera paniculata, Macaranga aleuritoides* and *Mastixiodendron pachyclado* in a Papua New Guinea Primary Forest

Kari Iamba[1], Patrick S. Michael[2]*, Danar Dono[3], Yusup Hidayat[4], Vojtech Novotny[5]

[1,3,4]Departemen Hama dan Penyakit Tumbuhan, Fakultas Pertanian, Universitas Padjadjaran, Jl.Raya Bandung-Sumedang Km.21, Jatinangor , 45363, Indonesia
[2]Department of Agriculture, PNG University of Technology, Papua New Guinea
[5]New Guinea Binatang Research Centre, Madang, Papua New Guinea

***Abstract*****—** *Community composition and species diversity of fruit-eating-insects were studied in a primary forest at Wanang, Madang, Papua New Guinea (PNG) using fruits regularly sampled and insects attacking them reared, preserved and identified. Sampling was done in different areas of the forest including low and high abundance of the host trees. Fruits of three predominant host trees, G. paniculata (Myristicaceae), M. aleuritoides (Euphorbiaceae) and M. pachyclados (Rubiaceae) were regularly collected and insects associated with them studied. The emergence from the fruits were 13 insect families and 16 species from G. paniculata, 17 insect families and 21 species from M. aleuritoides and 17 insect families and 25 species from M. pachyclados. Diversity assessment showed M. pachyclados was more diverse (H=2.0258) followed by G. paniculata (H=2.007). M. aleuritoides was the least diverse (H=1.443). A high percentage of scavengers and wood eaters were found in G. paniculata and M. aleuritoides. In M. pachyclados, more seed eaters, chewers and parasitoids were found instead. These results have implications for management of the community composition and diversity of the fruit-eating insects of the three host three species.*

***Keywords*****— Community composition, species diversity, fruit-eating-insects, Papua New Guinea.**

## I. INTRODUCTION

Frugivorous insect biodiversity has not been documented in New Guinea Forests in regard to their communities and composition on *G. paniculata*, *M. aleuritoides* and *M. pachyclados*. These trees are predominant in Wanang Conservation Area and throughout the New Guinea forests, and have economic importance to the local people. A tropical tree species supports a number of species of insect herbivores which are often large and unknown [1, 2]. [3] reared Dacine fruit flies (Tephritidae: Dacinae) from a sample size of more than 100 fruits weighing more than 1 kg of fruits from plant species while other insect taxa from this guild and seed predators in species of Lepidoptera, Coleoptera and Diptera were not studied [3]. A diversity of frugivorous insects exist in tropical forests were quantitatively reared. With 57 frugivorous weevil species representing 10,485 individuals from 326 woody plant species in lowland rain forest in PNG [4]. These frugivorous insects can be partitioned into two feeding guilds; mesocarp feeders (flesh feeders) and those feeding on endocarp (seed predators).

Plants possess chemical and mechanical defences in seeds versus mesocarp that adheres to these specific feeding guilds [4]. Seeds are often shield by high concentrations of secondary compounds [5, 6, 7, 8], thus contribute to narrow attack by group of specialized predators that possesses detoxifying counteract mechanisms unlike against generalists which lack such protection [9]. Scolytine beetles attack palms [10] while *Revena rubiginosa* Boheman (curculionidae) predates on seeds of single-stemmed palm *Syagrus romanzoffiana* Cham (Arecaceae) [11, 12]. [13] recorded about 60% of fruit attack by seed predators in which weevils, katydids, and moth larvae were predominant on understory palm *Calyptrogyne ghiesbreghtiana* [14]. Most seed-beetles are oval shape [15] and have dietary specialization [16].

Parasitoids also strive with insect since they depend on them as hosts to complete their life cycles. [17] and [18] studied seven species of Braconid parasitoids under sub-family Opiinae: *Doryctobracon areolatus* Szépligeti, *Utetes anastrephae* Viereck, and *Opius* sp. Muesebeck, and Alysiinae: *Asobara anastrephae* Muesebeck, *Phaenocarpa pericarpa* Foerster, *Idiasta delicata* Papp, and *Asobara* sp. Nees. [19] stated that *Braconid* wasps were frequently reared from *Cydia* sp. larvae (Tortricidae: Grapholitini) from understorey palm (*Calyptrogyne ghiesbreghtiana* Linden) in Costa Rica where fruits containing *Cydia* have oviposition punctures of parasitoid and explains high parasitism due to few adults reared. Twenty-two

*Braconid* species belonging to Agathidinae, Braconinae, Helconinae, Homolobinae and Rogadinae subfamilies were recorded from Brazil, Chile, Costa Rica, Guatemala, Mexico and Panama [20, 21]. In this study, the community composition and species diversity of host-specific fruit eating insects of *G. paniculata*, *M. aleuritoides* and *M. pachyclado* were studied.

## II. MATERIALS AND METHODS

### 2.1 Field Sampling

The study was conducted in a primary forest at Wanang Conservation Area (5$^o$13 ′S, 145$^o$04 ′E, 100 m.a.s.l), Madang, PNG [22, 23]. The map of the conservation area is shown in Fig. 1. [24] described the vegetation of the site as mixed evergreen rain forest on Latosol with a humid climate, and of mean annual rainfall of 3600 mm, having a mild dry season from July to September, and mean annual temperature of 26°C [25]. Fruits were sampled systematically following rows from an existing 50 ha forest plant plot in the Conservation Area and a few were sampled outside of the plot. Three locally abundant tree species were selected for the study: *G. paniculata*, *M. aleuritoides* and *M. pachyclados*. Sampling was done in different areas of the forest including both low and high abundance of the host trees. Fresh fallen fruits of each tree species was collected from the ground then were separately placed into plastic bags, given a unique tree number code and brought to the onsite laboratory. A fruit from each tree was sliced in half and photographed, together with unsliced fruits along with their respective tree number code.

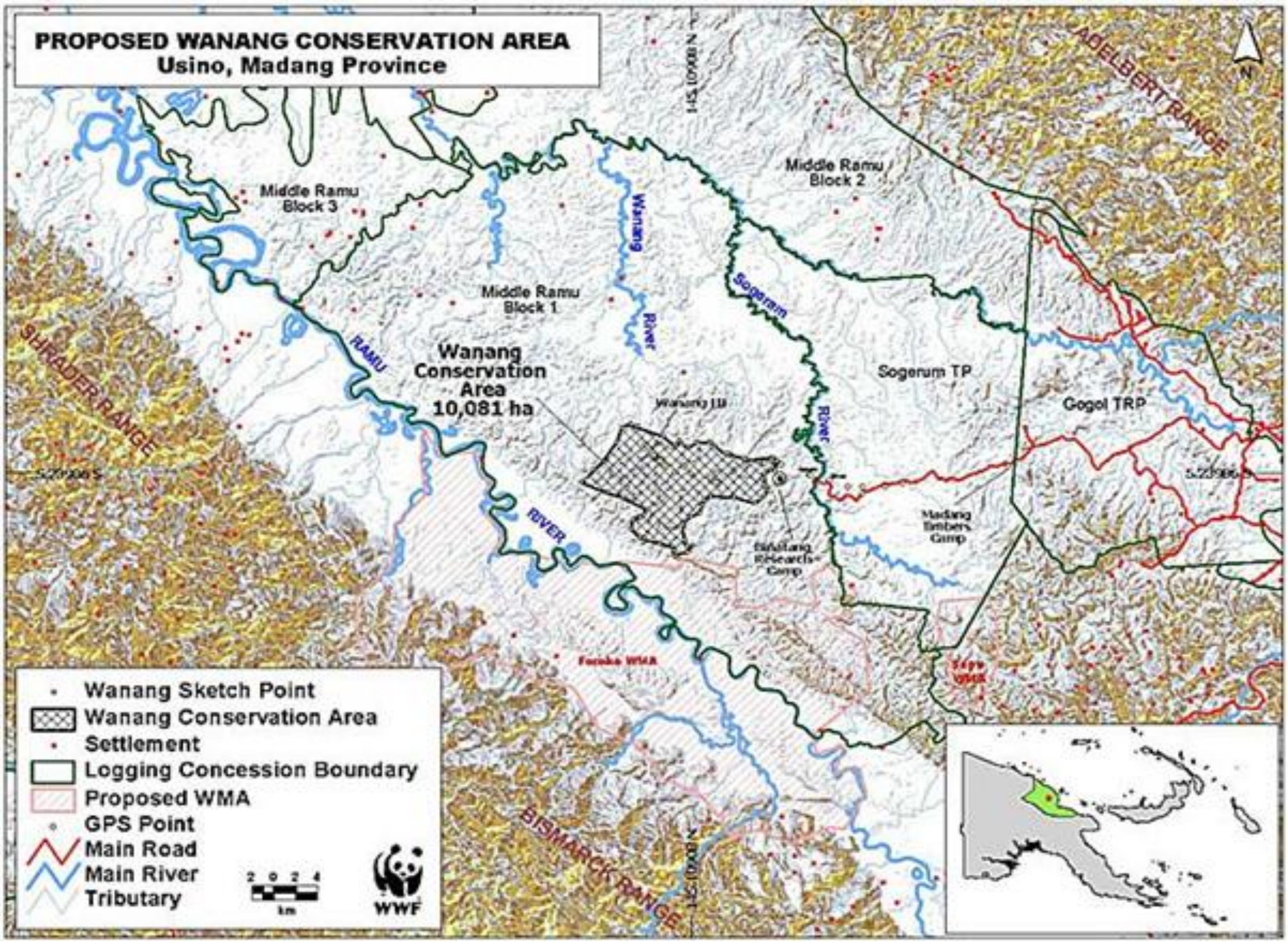

FIGURE 1. THE LOCALITY OF STUDY SITE, WANANG CONSERVATION AREA, MADANG, PNG

The fruits were then separated into plastic rearing containers (lunch boxes) and weighed on an electronic balance. Fruits from each tree represented by 3 fruit samples were sliced and measured (fruit and seed length, width, and fruit height) were measured. The rearing containers were closely monitored on a daily basis for insect emergence. Once insects emerged, they were collected by opening the side of the plastic led and collected with a medium sized plastic test tube and preserved in 99% ethanol.

### 2.2 Insect Sorting and Identification

All wet specimens were taken to the New Guinea Binatang Research Center (NGBRC) for identification. Identification was done using the aid of reference text books [26, 27], online insect databases (www.buglife.com), and insect database and reference collections of NGBRC. Insect specimens were initially sorted into morpho-species and given codes based on their distinct morphological features. Identification was done to genus level and coleopterans and lepidopterans to species level respectively. The resulting data on species abundance and richness of frugivorous insects were recorded and sorted using Microsoft Excel 2010.

### 2.3 Data Analysis

The Shannon-Wiener diversity index was used to measure the diversity of insects associated with each of the three host trees. Species diversity differs from species richness since diversity encompasses both the numbers of species present and the dominance or evenness of species in relation to one another [28].

$$\text{Shannon Index (H)} = -\sum_{i=1}^{s} p_i \, lnp_i$$

***p*** is the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N). **ln** is the natural log, $\sum$ is the sum of the calculations, and ***s*** is the number of species.

Menhinick's index was used to measure species richness [29], and served as a measure of the number of species found in a sample and species evenness, measure the relative abundance of different species making up the richness on each tree.

$$D = \frac{s}{\sqrt{N}}$$

where **s** equals the number of different species represented in a sample, and **N** equals the total number of individual in the sample.

Species evenness is also an important component of diversity indices [30, 31, 32] and expresses how evenly each species is distribution among different habitat (host trees).

$$\text{Species evenness (E)} = H/H_{max}$$

where $H_{max}$ = **ln** (N) and H = Shannon Index value. N is the number of species (species richness)

Feeding guilds are based on type of feeding mode and the fruit parts fed on as per [4, 9].

## III. RESULTS

A total of 91 fruit samples weighing 14.5 kg were collected from three host trees. A total of 28 samples collected from *G. paniculata* weighing 2.07 kg reared 184 individual insects, 33 samples from *M. aleuritoides* weighing 5.07 kg reared 1938 individual insects, and 30 samples from *M. pachyclados* weighing 3.77 kg reared 289 individual insects. The remaining samples weighing 3.63 kg did not rear any frugivorous insects. A total of 2, 414 individual insects emerged from a total fruit sample weighing 10.90 kg. Thirteen (13) insect families and 16 species emerged from *G. paniculata*, seventeen (17) insect families and 21 species emerged from *M. aleuritoides* while seventeen (17) insect families and 25 species emerged from *M. pachyclados*.

The species diversity, richness, evenness and similarity of the frugivorous insects reared from each tree species are shown in Table 1. All dipterans and hymenopterans, and few lepidopterans and hemipterans were sorted into morpho-species and given codes based on their distinct morphological features.

The feeding guilds of the insects reared are shown in Figure 2. There were more scavengers in *G. paniculata* than in *M. aleuritoides* than in *M. pachyclados*. In addition, there were more wood eaters in *M. aleuritoides* than in *G. paniculata* and the least was in *M. pachyclados.* Seed predator and chewer were abundant in *M. pachyclados,* compared to the other two tree species.

### TABLE 1
### ABUNDANCE AND COMPOSITION OF INSECTS

| Insect Taxa | Number of individual insects per Tree | | |
|---|---|---|---|
| | *G. paniculata* | *M. aleuritoides* | *M. pachyclados* |
| Anisopodidae (Diptera) | 1 (0.543478261) | 1 (0.051519835) | 1 (0.346020761) |
| Agonoxenidae (Lepidoptera) | 0 (0) | 2 (0.10303967) | 0 (0) |
| *Araecerus* sp .1 ( Anthribidae: Coleoptera) | 0 (0) | 0 (0) | 10 (3.460207612) |
| *Araecerus* sp.2 (Anthribidae: Coleoptera) | 0 (0) | 0 (0) | 9 (3.114186851) |
| *Araecerus* sp.3 ( Anthribidae: Coleoptera) | 0 (0) | 0 (0) | 3 (1.038062284) |
| *Araecerus* sp.4 ( Anthribidae: Coleoptera) | 0 (0) | 0 (0) | 1 (0.346020761) |
| *Araecerus* sp.5 ( Anthribidae: Coleoptera) | 0 (0) | 0 (0) | 2 (0.692041522) |
| *Baris* sp. (Curculionidae: Coleoptera) | 0 (0) | 0 (0) | 44 (15.22491349) |
| *Blastobasis* sp. (Blastobasidae: Lepidoptera) | 6 (3.260869565) | 0 (0) | 1 (0.346020761) |
| Braconidae (Hymenoptera) | 0 (0) | 6 (0.309119011) | 73 (25.25951557) |
| *Cillaeus* sp. (Nitidulidae: Coleoptera) | 6 (3.260869565) | 7 (0.360638846) | 0 (0) |
| *Coccotrypes dactyliperda* (Scolytinae: Coleoptera) | 29 (15.76086957) | 1112 (57.29005667) | 16 (5.53633218 |
| *Conotrachelus* sp. (Curculionidae: Coleoptera) | 0 (0) | 0 (0) | 6 (2.076124567) |
| Drosophilidae (Diptera) | 74 (40.2173913) | 147 (7.573415765) | 13 (4.498269896) |
| Eucoilidae (Hymenoptera) | 0 (0) | 0 (0) | 1 (0.346020761) |
| Eulophidae (Hymenoptera) | 0 (0) | 0 (0) | 1 (0.346020761) |
| Formicidae (Hymenoptera) | 0 (0) | 1 (0.051519835) | 0 (0) |
| *Haplonyx* sp. (Curculionidae: Coleoptera) | 0 (0) | 13 (0.669757857) | 1 (0.346020761) |
| Ichneumonoidea (Hymenoptera) | 0 (0) | 0 (0) | 1 (0.346020761) |
| Lonchaeidae (Diptera) | 8 (4.347826087) | 0 (0) | 0 (0) |
| | | | |
| Lygaeidae (Hemiptera) | 1 (0.543478261) | 1 (0.051519835) | 0 (0) |
| *Mimemodes* sp. (Coccinellidae: Coleoptera) | 1 (0.543478261) | 0 (0) | 0 (0) |
| Muscidae (Diptera) | 0 (0) | 2 (0.10303967) | 5 (1.730103806) |
| *Mussidia pectinicornella* (Pyralidae: Lepidoptera) | 0 (0) | 0 (0) | 72 (24.91349481) |
| Mycetophilidae (Diptera) | 1 (0.543478261) | 0 (0) | 0 (0) |
| New moth family (Lepidoptera) | 2 (1.086956522) | 0 (0) | 5 (1.730103806) |
| Periscelididae (Diptera) | 5 (2.717391304) | 332 (17.10458527) | 2 (0.692041522) |
| *Phenolia* sp.1 (Nitidulidae: Coleoptera) | 0 (0) | 2 (0.10303967) | 0 (0) |
| *Phenolia* sp.2 (Nitidulidae: Coleoptera) | 5 (2.717391304) | 1 (0.051519835) | 4 (1.384083045) |
| Phoridae (Diptera) | 0 (0) | 1 (0.051519835) | 1 (0.346020761) |
| Psychodidae (Diptera) | 20 (10.86956522) | 156 (8.037094281) | 0 (0) |
| *Spaerosoma* sp. (Coccinellidae: Coleoptera) | 0 (0) | 49 (2.524471922) | 0 (0) |
| *Thiotricha* sp. (Gelechiidae: Lepidoptera) | 0 (0) | 6 (0.309119011) | 0 (0) |
| Tipulidae (Diptera) | 15 (8.152173913) | 5 (0.257599176) | 14 (4.844290657) |
| Torymidae (Hymenoptera) | 0 (0) | 3 (0.154559505) | 0 (0) |
| *Xyleborinus saxeseni* (Scolytinae: Coleoptera) | 2 (1.086956522) | 70 (3.60638846) | 1 (0.346020761) |
| *Xyleborus metacuneolus* (Scolytinae: Coleoptera) | 8 (4.347826087) | 24 (1.236476043) | 2 (0.692041522) |
| | | | |
| **Total** | **184 (100)** | **1941 (100)** | **289 (100)** |

***Note: a) G. paniculata: Diversity index (H) = 2.006637167, Richness index (D) = 1.179535649, Evenness index (E) = 0.723741373***

***b). M. aleuritoides: Diversity index (H) = 1.442591566, Richness index (D) = 0.477026393, Evenness index (E) = 0.473831806***

***c). M. pachyclados: Diversity index (H) = 2.258377854, Richness index (D) = 1.470588235, Evenness index (E) = 0.701604528***

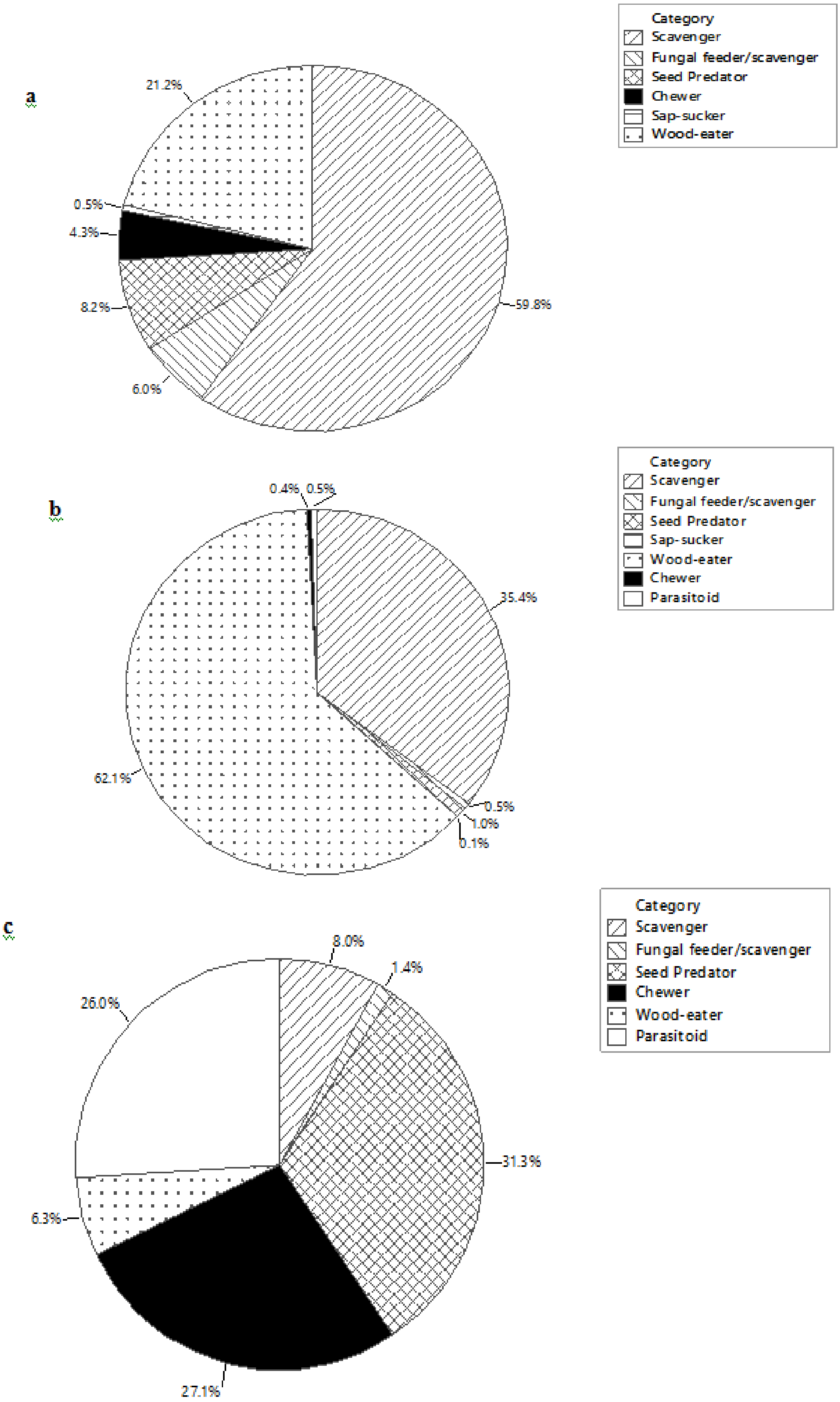

**FIGURE 2. FEEDING GUILDS OF INSECTS ON (a) *G. paniculata*, (b) *M. aleuritoides* and (c) *M. pachyclados***

## IV. DISCUSSION

Fruit size and morphology can influence chances of weevil attack to fruits [4]. Only fruits with sufficient mesocarp (fleshiness) with large seeds concurrently host both seed- and flesh-eaters where weevils preferably avoid small fruits due to lack of substantial resources for larval development. However, weevils also avoid fruits of larger than average size-fruits that have very thick and hard endocarp which is recognized as a significant barrier to seed predation [33]. Fruits of the tree species had generally thin mesocarp thickness 2.5 mm (*G. paniculata*), 1.8 mm (*M. aleuritoides*) and 1.8 mm (*M. pachyclados*) with corresponding seed (endocarp) thickness of 5 mm, 4 mm and 4.3 mm, respectively.

The tree species had different fruit-eating insect diversity (H), species richness (D) and species evenness (E). The insect diversity associated with fruits was highest in *M. pachyclados* (25 insect species, H= 2.0258) due to larger seed size and soft endocarp (seed) for ease of penetration by frugivorous insect larvae. *G. paniculata* (H= 2.007) with second highest insect diversity was attributed to its soft mesocarp and semi-soft endocarp (seed) that permits penetration by insect larvae. *M. aleuritoides* (H= 1.443) was least diverse probably due to chemical and mechanical defenses mechanisms of the mesocarp [5, 6, 8] and attacked only by specialists, e.g. seed predators which possess detoxifying mechanisms [9]. Even though *M. aleuritoides* had the highest species number (21 insect species) than *G. paniculata* (16 insect species, E= 0.724), this insect was not well distributed on *M. aleuritoides* (E= 0.474).

As Table 1 shows, *Coccotrypes dactyliperda* (Scolytinae) had very high abundance (1112 individuals) while other insect species had abundance quite lower than that (abundance values not close together). Since *C. dactyliperda* numerically dominates the other 20 insect species, *M. aleuritoides* is considered less diverse than *G. paniculata*. Evenness indices ranges from 0 when most individuals belong to a few species, while close to 1, when species are nearly equally abundant, and often used to standardize abundance [34, 35]. It is obvious that insect species are not nearly equally abundant on *M. aleuritoides* (E= 0.474).

The feeding guilds based on the food resources provided or associated with fruits were shown in Figure 2. Drosophilidae infests small fruits and cherries of a variety of wild, ornamental, and uncultivated hosts during both ripening or overripe stages, and even attacks damaged fallen fruits [36] of *G. paniculata* therefore they can be regarded as both frugivores and scavengers. Both Drosophilidae and Tephritid flies feed on sugar either from split fruit, floral nectar, extrafloral nectar, sap, yeast or insect honeydew [37]. Tephritid flies were not reared in this study mainly due to very thin fruit mesocarp of *G. paniculata* (2.5 mm), *M. aleuritoides* (1.8 mm) and *M. pachyclados* (1.8 mm). Female tephritid flies usually deposit their eggs 2-4 mm under the aril and needs sufficient mesocarp (>4 mm) to provide enough food substrate for the developing larvae [38].

All the fruits studied did not support the oviposition requirement and proceeding larval development of tephritid flies. An experiment performed by [36] showed that tephritid fly (*Bactrocera invadens* Drew) preferred to oviposit in mango variety with thicker mesocarp than those with lesser mesocarp. Nitidulidae (*Phenolia* & *Cillaeus* sp.) are considered both scavengers feeding on decaying matter and as fungal-feeders or mycetophagous [9; 40]. *Coccotrypes dactyliperda* (Scolytinae: Coleoptera) predominates *M. aleuritoides* and emerged via seeds. *C. dactyliperda* are commonly known as bark (wood) beetles and the reason they dominate *M. aleuritoides* is probably due to the woody nature of seeds. Periscelididae, Psychodidae and Drosophilidae were abundant on *M. aleuritoides* due to their scavenging ability [41] when the fruit rotted.

Braconid wasps were abundant on *M. pachyclados* [33]. *Mussidia pectinicornella* (Pyralidae: Lepidoptera) and *Baris* sp. (Curculionidae: Coleoptera) were prevalent on *M. pachyclados* and might have served as host for Braconid wasps. Parasitism of host larvae by female *Braconid* wasps may have occurred prior to rearing. Singleton insect species in any of the three fruit trees having abundance of only one individual may indicate the fruit as alternate host where a suitable host seems rare or absent. Singleton species such as parasitic wasps (Eucoilidae & Eulophidae) as observed only on *M. pachyclados* might be due to low host-larvae number associated with the fruits. There is a need to investigate Eucoilid and Eulophid parasitic wasps and their host as there is few or no detail information on these wasps, particularly in PNG forest.

## V. CONCLUSION

The diversity of fruit-eating insects in PNG forests and their roles in maintaining high plant diversity in the tropical forests are not often documented. The resulted of this study showed that the diversity of frugivorous insects differ between tree species. The highest insect diversity was recorded on *M. pachyclados* (H=2.0258), followed by *G. paniculata* (H=2.007) and *M. aleuritoides* (H=1.443). Feeding guild assessment showed there were more scavengers and wood eaters in *G. paniculata* and *M. aleuritoides* than in *M. pachyclados*. Comparatively, there were more seed eaters, chewers and parasitoids in *M. pachyclados*. Communities of frugivorous insects feed on fruits of tropical forest trees and their feeding guilds pertain to distribution and thus diversity on plants. Therefore, the results of the feeding communities of fruit-eating insects on the tress thus contribute to better understanding of the ecology of tropical forests, particularly the dynamics of tree species, and the potential role of frugivorous insects. The findings of this study have implication for management of the fruit-eating-insects of primary forests of PNG.

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