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Field Studies of Insect Visitation and Notes on the Population Ecology of Nipa Palm [*Nypa fruticans* (Wurmb.) Thunberg]

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The generalization that palms mainly exhibit anemophily has been disregarded and the idea that palm species are serviced by a specific group of pollinating insects has been accepted. The alternative concept that palm pollination is through more than one group of insects was tested by studying the diversity and ecological role of insects visiting the flowers of nipa palm (*Nypa fruticans*) to address the question whether or not nipa palm has a specialized pollination syndrome or whether pollination occurs via a group of insects or not. At least 25 families from the orders Diptera, Coleoptera, Dermaptera, Hymenoptera and Hemiptera were recorded visiting the flowers of nipa. Results showed that insects from the families Drosophilidae (Diptera) and Nitidulidae (Coleoptera) and Curculionidae (Coleoptera) are the main insect visitors of nipa inflorescence and are the likely pollinators. Moreover, the absence of insect-specificity in the pollen vector of nipa supports the concept that pollination is likely to be in the general sense "entomophilous" with the predominance of cantharophily.

Key Words: *Nypa fruticans*, pollination ecology, insect diversity, animal-plant interaction, palm pollination

INTRODUCTION

Reproduction in plants occurs through modified vegetative parts, such as roots, stems and leaves, or through the fusion of gametes in pollination and dispersal of the young embryo inside the seed or fruit. The pollination process is the transfer of pollen from a stamen to a pistil in the same plant or between two plants. Pollination occurs in a wide range of mechanisms that ensure an appropriate balance in the genetic make-up of the species. Moreover, most plants rely on several factors of pollination such as animals and/or the wind for reproduction.

Wind pollination or anemophily occurs when pollen grains are carried by the wind from one flower to another. Plants that are pollinated by wind or anemophiles have long stamens and pistils. These characters have evolved, particularly the well-exposed stamens, so that the pollen carried by wind could easily be captured by the female flower. Another distinct character is the large feathery stigma for easily trapping air-borne pollen grains. These flowers do not need to attract animal pollinators, thus they are characterized by being dull colored, unscented and with small or no petals at all since animals do not need to land on them (Faegri and van der Pijl 1966).

Animal pollination occurs when pollen grains are carried by animal pollen vectors, which are usually insects. Plants that are animal-pollinated have sticky and ornate pollen structure (Faegri and van der Pijl 1966). Furthermore, flowers have evolved characters that would attract insects such as bees, butterflies, moths, flies and even birds, such as hummingbirds. These floral visitors pollinate plants accidentally in the essence of looking for food such as pollen and nectar. The benefits derived by plants from these floral visitors vary and only floral visitors, which continuously, consistently and efficiently perform pollination services, are favorably attracted to the plants and are eventually also rewarded.

In the study of pollination, palms are among the most important angiosperms or flowering plants because these exhibit both wind and animal pollination. These features place the palms at the center of understanding the evolution of palms as well as plant-pollinator interaction. Furthermore, palms are mostly tropical with a few subtropical species. The diversity of palms is highest in the biogeographic region of Malesia (Indonesia, Singapore, Malaysia, Brunei, Papua New Guinea and the Philippines) and in South America. Thus, with the study of palm species in Asia, the understanding of pollination in palms will likely be modified (Barford et al. 2011).

In Asia, a widely distributed palm species is the nipa palm [*Nypa fruticans* (Wurmb.) Thunberg]. Similar to other palms, nipa has a conspicuous inflorescence, arising as a single stem from the leaf axil terminating into the pistillate head and lateral branches terminating into staminate columns, which led to the conclusion that nipa is pollinated mainly by wind (Uhl 1972). But the brightly colored yellow-to-orange flower and the sticky, ornate pollen structure suggest that these are pollinated by animals. Henderson (1986) stressed the importance of re-investigating the pollinators of nipa in consideration of the unusual morphology and isolated systematic position of nipa.

Economically, nipa is an important source of fiber, beverage and roofing materials in Southeast Asia where it is widely distributed. The most important product from nipa is the sap for tuba (coconut toddy) and biofuel products which are obtained from the fruit. Consequently, fruit setting is related to successful pollination of the female inflorescence. For this reason, it is imperative to study the significance of insect visitors on nipa inflorescence. In spite of the importance of nipa as a potential driver of economic growth, there have been no studies with regard to the insect visitors of nipa inflorescence in the Philippines.

To explain the concept of pollination in nipa, this study aims mainly to determine the interaction and diversity of the insect visitors to the nipa inflorescence. Specifically, the study aims to identify the arthropods visiting nipa inflorescence, and to analyze their activity and diversity.

MATERIAL AND METHODS

Time and Place of Study

This study was conducted from August to November of 2013 in the coastal municipality of Infanta, Quezon which is globally positioned at 14°44'33"N 121°38'58"E. Specifically, the nipa plantation is located at Purok Tangal, Barangay Binonoan, which is 7–8 km from the town proper (Infanta Municipal Profile 2014).

Field Observation of Insect Visitors

Field observation was done by choosing ten inflorescences at the stage of initiation along the transect line. The inflorescences were tagged using plastic laminated numbers. Ocular observations were done on insect visitation and on flower morphology for 3 consecutive weeks. Data were gathered during the daytime peak of insect activity, which occurs from 10:00 a.m. to 12:00 noon. Ocular identification was done for insects visiting the inflorescence upon their arrival at the flower. Insect visitors unidentified during the time of the survey were listed as species 1, species 2, species 3…and so forth. After the ocular identification, sample specimens were collected by handpicking, using fine-tip forceps for sedentary insects, and net sweeping, using entomological nets for flying insects. The specimens were brought to the laboratory for verification and identification. The frequency of insect visits was recorded based on their presence (+)/absence (-) by observing 10 flowers three times for 15 min. The frequencies were then tabulated.

Data on insect abundance in the inflorescence, behavior and purpose of visit as well as the activity pattern of insects were recorded following the methods of Listabarth (2001). Insect abundance was recorded based on criteria listed as follows: not observed (-); single individuals, ranging from 1 to 3 (+); few individuals, ranging from 4 to 10 (++), and common for those occurring more than 10 times (+++). The behavior of insects was defined as follows: pollen feeding or collecting (p), tissue feeding (t), mating (m), flower harvesting (h), and predation (pr). Furthermore, the activity pattern was defined as follows: come and go (cg); few movements between inflorescences (fm); and almost sedentary (s).

Pollinators of nipa were characterized based on the following criteria: presence in abundant numbers, capability to carry pollen, visit to both male and female flowers, and availability during data collection. On the other hand, predators were characterized based on the feeding guild, while pests were identified as insects observed to be present in the inflorescence and exploiting resources offered by the inflorescence without a corresponding benefit for the plant.

Insect Collection and Preservation for Diversity Analysis

A transect line, about 1 km long, was positioned in the study area for insect collection and observation of insect visitors. Four sampling stations were established in the transect lines marked with red ribbons and set at 125 m [21 m above sea level (masl), 14°41′37.0″N 121°38′17.9″E], 375 m [14 masl, N14°41′34.9″N 121°38′18.3″E], 625 m [14 masl, 14°41′33.0″N 121°38′21.5″E] and 875 m [14 masl, 14° 41′28.9″N 121°38′21.3″E], respectively. In each sampling station, the nearest inflorescence at the stage of anthesis was used for collecting arthropod visitors. A total of four samples were collected at around 10:00 a.m. to 12:00 noon during a single sampling trip. Data was collected once a month for four consecutive months.

The arthropods clumped on the inflorescence were collected by gathering the whole inflorescence along with the insects. Collections were done by enclosing the whole inflorescence with a large plastic zip bag. This method also traps the insects which are sedentary on the inflorescence and those visiting the inflorescence at the time of sampling. The enclosed inflorescence was cut from the base and sprayed with 95% ethyl alcohol to kill the collected arthropods.

A representative sample of each species collected was preserved in vials with 85% ethyl alcohol for identification. Curatorial activities were done by dry and wet methods including slide mounts. For the dry method, representative adult specimens were mounted on size 1 and size 2 insect pins, while smaller insects were mounted on card points. The insects were stored in an airtight wooden insect box with naphthalene balls to prevent damage by storage pests such as dermestids and ants. On the other hand, for the wet method, specimens were preserved in Eppendorf vials with 85% ethyl alcohol. The vials were stored in an alcohol-filled jar. Microarthropods collected during the sampling period were mounted on slides with Hoyer's mounting media as mountant. Collections were labeled accordingly, indicating the place and date of collection and the collector. Voucher specimens were deposited at the Insect Taxonomy Laboratory, Institute of Weed Science, Entomology and Plant Pathology, College of Agriculture and Food Science, University of the Philippines Los Baños for reference collection and future studies.

Taxonomic Identification

The collected specimens were sorted with the aid of a dissecting microscope. Specimens were identified to the nearest taxa possible using available taxonomic keys. For those taxa which are difficult to identify, the help of taxonomic experts was sought to confirm identification of each specimen.

Measurement of Diversity Indices and Abundance

Species diversity was measured by the Shannon-Weiner Index of Diversity. Species richness, diversity indices, evenness, and relative abundance were computed using PAST 3 Version 2 (Hammer et al. 2001).

RESULTS AND DISCUSSION

Field Observation of Insect Visitors

A single species of mites and 26 species of insects from the orders Dermaptera, Coleoptera, Diptera, Hymenoptera and Hemiptera were observed in the inflorescence (Table 1). Insects attracted to the inflorescence were mostly from the orders Diptera (48%), Coleoptera (22%) and Hymenoptera (15%). The most frequently observed insect visitors were from the families Drosophilidae, Nitidulidae, Formicidae and Curculionidae. It is worthwhile to mention the frequent occurrence of the lone mite species, especially during the late maturation phase and early anthesis phase of the inflorescence. Furthermore, predators such as earwigs and rove beetles were present.

The various insects visiting the inflorescence were mostly attracted by the pollen of the conspicuous flowers. Most species of insects observed in the inflorescence are pollen feeders. Some insect visitors are known also as sap feeders, detritivores, and predators. Some insects were observed mating and ovipositing in the inflorescence; others fed on the tissues. Additionally, some of these insects are potentially pollinating the inflorescence of *Nypa fruticans*.

Diptera. The most dominant families recorded were true flies. These flies are scavengers feeding on sap, yeast and pollen. Some flies are also predatory and feed upon other insects attracted to the inflorescence, while other flies are attracted to the inflorescence because this serves as a good site for oviposition and development of the larvae. Among the most dominant flies visiting the inflorescence are from the family Drosophilidae (Fig. 1a), known as fruit, vinegar or pomace flies. These are commonly found feeding on fruits, plant sap, fungi and flowers. Three species were observed in the inflorescence. Among the fruit flies, *Drosophila (Drosophila) hypocausta* Osten-Sacken was observed even before anthesis and throughout the duration of the staminate phase. This fly was found feeding on pollen and sap of the inflorescence. *D. hypocausta* was abundant and widely attracted to the nipa inflorescence, and some were observed loaded with pollen on their body parts, particularly the legs and setae of the pronotum. Another species of Drosophilidae is *Drosophila (Sophopora)* sp. which was commonly found on the decaying staminate inflorescence and damaged stalks. Lastly, an undetermined *Drosophila* sp. was found frequently on the prophyll and bracts. The occurrence and abundance of fruit flies and their frequency may be explained by the presence of pollen. Feeding sites for the larvae in large numbers might be due to the fermenting sap of nipa.

Essig (1973) conducted exploratory studies in New Guinea and conceptualized the idea that nipa palms are pollinated by drosophilid flies. This concept was based on the observation that drosophiline flies are abundant, and that they visit the male and female flowers and are covered with pollen. Thus, Essig (1973) suggested that nipa serves as burrowing-feeding site for the larvae of the Drosophilidae. As the adult flies emerge, they become covered with pollen and look for another inflorescence that is beginning to bloom. Essig's conclusion was corroborated by Henderson (1986) and Tomlinson (1986)

Table 1. Insect visitors of nipa palm [*Nypa fruticans* (Wurmb.) Thunberg] inflorescence.

ORDER/FAMILY	Frequency[1]	Abundance[2]	Activity[3]	Purpose[4]
DERMAPTERA				
Chelisochidae	23.33	+	*s*	*pr*
HEMIPTERA				
Lophopidae	3.33	+	*cg*	*t*
Aphidae	3.33	+	*s*	*t*
COLEOPTERA				
Staphylinidae	13.33	+	*s*	*pr*
Nitidulidae (*Epuraea* sp.)	70.00	+++	*s*	*p, t, m*
(*Haptorcus* sp.)	6.67	+	*s*	*p, t, m*
Curculionidae (Rhynchoporini)	23.33	+	*s*	*p, t, m*
(Apionini)	6.67	+	*s*	*p, t, m*
Chrysomelidae	3.33	+	*fm*	*t*
DIPTERA				
Tipulidae	3.33	+	*fm*	*p*
Micropezidae	33.33	+	*fm*	*P*
Ceratopogonidae	10.00	+	*cg*	*Pr*
Phoridae	16.67	+	*s*	*Pr*
Syrphidae	36.67	+	*cg*	*P*
Conopidae	3.33	+	*cg*	*P*
Diastadidae	10.00	++	*s*	*P*
Drosophilidae (*Drosophila hypocausta*)	80.00	+++	*s*	*p, m*
(*Drosophila (Sophopora)* sp.	80.00	+++	*s*	*p, m*
***Drosophila* (sp. 1)**	33.33	+++	*s*	*p, m*
Otitidae	3.33	+	*cg*	*P*
Muscidae	36.67	+	*s*	*p, m*
Platypezidae	6.67	+	*fm*	*Pr*
HYMENOPTERA				
Formicidae (sp. 1)	43.33	+++	*cg*	*P*
(sp. 2)	3.33	+	*cg*	*p, pr*
Apidae (*Tetragonula* sp.)	33.33	+	*cg*	*P*
(*Apis dorsata*)	3.33	+	*cg*	*P*
ACARI				
Mites	56.67	+++	*s*	*Pr*

[1]Frequency is based on presence/absence on three 15-min observations of 10 inflorescences.
[2]Abundance: +, single individuals (1-3); ++, few individuals (4-10) and +++, common (>>10).
[3]Activity pattern defined as: fm, few movements; cg, come and go; s, sedentary
[4]Insect behavior as: p, pollen feeder; t, tissue feeding/sucking; m, mating; pr, predation.

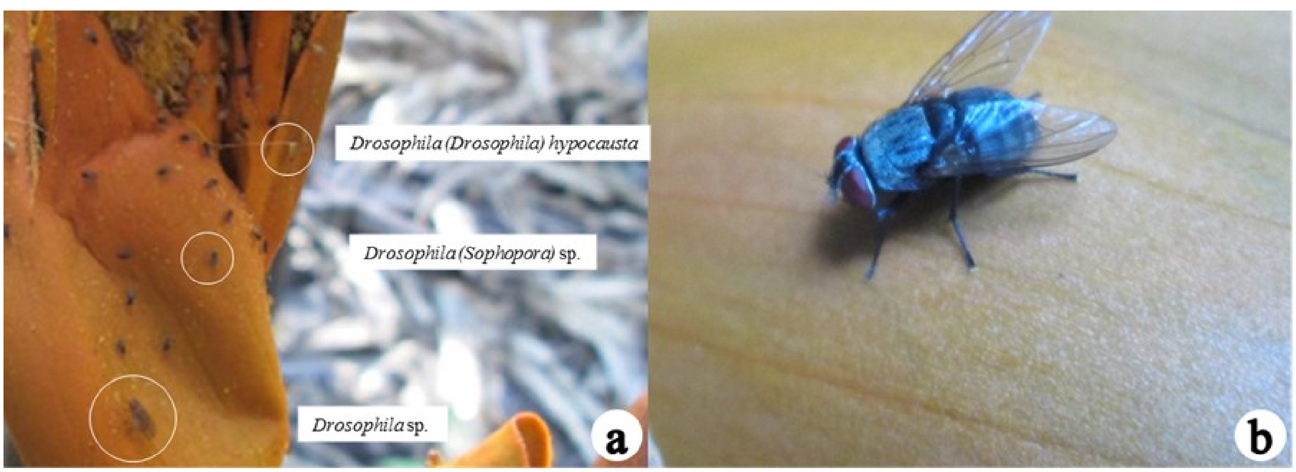

Fig. 1. Flies (Diptera) attracted to nipa [*Nypa fruticans* (Wurmb.) Thunberg] inflorescence: (a) Drosophilidae and (b) Muscidae.

in their reviews. Furthermore, Uhl and Moore (1977) correlated nipa inflorescence with palm pollination.

We also found other flies visiting the inflorescence. *Musca* sp. were attracted to the nipa inflorescence (Fig. 1b). Some unopened inflorescences were observed to be detached near the stalk due to feeding-burrowing of the larvae of *Musca* sp. (Fig. 2a). These flies were observed hovering even before anthesis and laid eggs on the bracts (Fig. 2b). Upon hatching into the larvae tunnel, the eggs fed on the soft tissues of the inflorescence. On the male inflorescence, there were exit holes large enough to indicate that these were exit holes for the larvae of *Musca*

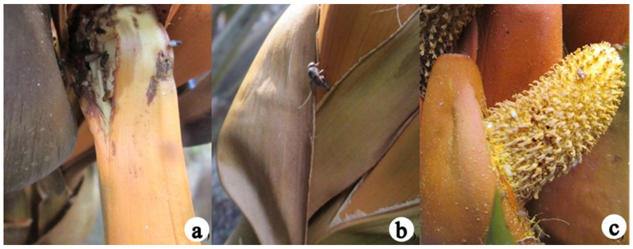

Fig. 2. Damage caused by insects: (a) inflorescence with nearly detached stalk due to excessive, feeding-burrowing of larvae, (b) *Musca* sp. ovipositing, and (c) exit holes of larvae.

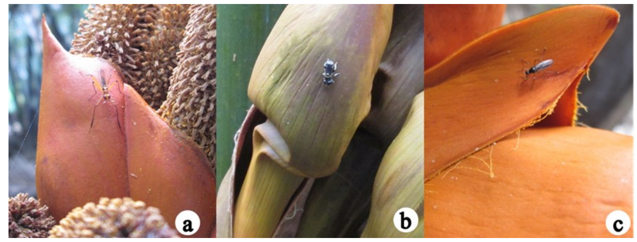

Fig. 3. Other insect visitors from the Order Diptera: (a) stilt-legged flies (Micropezidae), (b) hover flies (Syrphidae), and (c) dipteran predator (Platypezidae).

Fig. 4. Insect visitors from the order Coleoptera: (a) Nitidulidae (*Epuraea* sp.) and (b) Curculionidae (Apionini).

sp. (Fig. 2c). Stilt-legged flies (Micropezidae) fed on the detached pollen, adhering to the bracts as well as on the decaying inflorescence. Thick-headed flies (Conopidae) and hover flies (Syrphidae) grazed on the surface of bracts in the inflorescence (Fig. 3).

Coleoptera. Beetles, specifically the sap beetles (Nitidulidae) and weevils (Curculionidae), are among the most important visitors in the inflorescence of nipa. In our study, these insects were found covered with pollen as they moved around the male inflorescences.

Sap beetles from the genus *Epuraea* were the most abundant in the nipa inflorescence (Fig. 4a). *Epuraea* sp. were found commonly on the staminal columns probably feeding on pollen and sap. *Epuraea* sp. were observed to be present even before anthesis although only a few individuals were recorded. During the later stages of anthesis, these species of sap beetles were numerous and dominated the staminate spikes. Some individuals were also mating in the inflorescences and perhaps laying eggs on the flowers. On the other hand, *Haptorcus* sp. were observed mostly on the bracts and between the individual young fruits of the pistillate head. The sap beetles were found nesting on the crevices of the inflorescence, preferring the bracts, which provided them shelter and protection against predators (Sakai 2002).

Another family of beetles that play an important role in pollination are the weevils (Curculionidae). Two species were observed on the inflorescences. There appears to be a partitioning of shelter for these two species of weevils inhabiting the inflorescence. The larger species (Rhynchophorini) were found mostly on the large leathery bracts of the male inflorescence. There was an opportunity wherein a pair of these larger weevils was observed mating on the staminal column and were covered with pollen on their legs, abdomen, elytra and mouthparts. Some of these beetles were also observed on the female inflorescence. On the other hand, the smaller weevils (Apionini) were found mostly on the spaces between pistillate flowers and on the bracts of the pistillate head. There were instances wherein these smaller weevils were observed visiting the locular canals probably to feed on the tissues inside the locular canals of the pistillate flower. These were also found mating on the inflorescence and probably also laying eggs on the bracts or on the spaces between pistillate flowers. During the conduct of the observation, there were only a few individuals recorded on the inflorescence but insect collection from the flowers suggests that these beetles are numerous on the bracts. These were found hiding on the bracts of the inflorescence from the collected flowers of nipa. According to Sakai (2002), the interior of the bracts of the inflorescence provide shelter and protection against predators of these insects.

Staphylinidae or rove beetles are also found numerous in the inflorescence particularly in the bracts and between staminate flowers. Rove beetles are gregarious and feed on sap, pollen and other arthropods.

The importance of the two families of beetles, Nitidulidae and Curculionidae, in the pollination of Palmae has already been recognized by Barford et al. (2011), Henderson (1986) and Silberbauer-Gottsberger (1990). Henderson (1986) concluded that the original pollination mechanism of palms is cantharophily or that extant palm families are pollinated by beetles. Observations and collections of insect visitors establish the role of beetles as pollinators of *Nypa fruticans*, specifically the weevils and sap beetles which were observed in large numbers in the inflorescence. More importantly, these beetles become covered with pollen and visit the male spikes and the pistillate head of nipa inflorescence. On the other hand, the rove beetles (Staphylinidae) may have been disregarded by Henderson (1986) as pollinators due to their irrelevant size and limited pollen carrying capacity. In our study, we found that these beetles play a role in the pollination of nipa because they visited both the male and female flowers. The rove beetles were also observed to have pollen adhering to their bodies.

Hymenoptera. Ants and bees were found visiting nipa in the study area (Fig. 5). Two species of ants were observed in the pistillate head. These ants were observed feeding in the locular canals, which have gelatinous secretions on the stigmatic opening of the carpels. The presence of ants can also be explained by the presence of aphids which serve as a source of honeydew for ants.

The bees observed in the area were from the family Apidae. The smaller visitor belongs to the genus *Tetragonula* while the other is the honeybee, *Apis dorsata*. The bees gather pollen as they gregariously hover over the male inflorescence. The gathering process, especially for *A. dorsata*, detaches a large amount of pollen that falls on the bracts and other parts of the inflorescence. These detached pollens serve as food for other insect visitors in the area.

Although the bees were not observed visiting the male inflorescence, they may have indirectly played a role in pollination. The pollen-gathering behavior of *A. dorsata*, moving up and down the inflorescence, stimulates other insect visitors that are present in the inflorescence to leave and look for another feeding area. In this sense, these smaller insect visitors from the male inflorescence carry pollen on their body parts and look for another inflorescence which may have the pistillate head emerging first and then they transfer this pollen to the stigma of a receptive female flower, resulting in pollination of nipa.

Other insects and arthropods. Insects are also attracted to the inflorescence due to the presence of prey and other arthropods. An example is the earwigs preying on eggs and young instar larvae of flies. The flies, as discussed earlier, lay eggs on the bracts of the inflorescence and the young larvae tunnels on the soft tissues of the rachillae and stalk. Earwigs are also detritus feeders and feed on pollen. They are nocturnal insects and should be less observed during the day but during the conduct of the study, they were collected numerously. The large prophylls and bracts of the inflorescence serve as shelter for earwigs. Furthermore, the eggs of earwigs are probably laid on the inflorescence or between the leaves of nipa. The mangrove environment is mostly wet and covered with water, and thus it would be impossible for the earwigs to brood their young on the soil.

Fig. 5. Insect visitors from the order Hymenoptera: (a) ants (Formicidae), and (b) *Apis dorsata* (Apidae).

Insects from the order Hemiptera were also observed in the inflorescence. These insects were observed to be less in number. Among them are from the family Lophophidae and Aphidae. The presence of aphids can also be another reason for the presence of ants in the inflorescence.

Mites were also recorded in the area. They were observed to be parasitic to sap beetles *Epuraea* and were frequently found on the inflorescence. Consequently, the mites were abundant where *Epuraea* sp. were also frequently observed. Identification of these mite species can be useful in managing nipa plantations. Furthermore, mites can also parasitize on species of weevils and serve as prey for the predatory rove beetles observed in the inflorescence.

Diversity of Insect Visitors to the Nipa Inflorescence

The community structure of arthropods attracted to the nipa inflorescence was described. There were 22 species of insects and two other arthropods (mites and spiders) recorded during the collection. Of these 22 species of insects, 27% belongs to Hymenoptera, 25% to Coleoptera and 16% to the order Diptera. The highest number of species was recorded in the month of September with 17, followed by October with 16, November with 14, and August with 13 species, respectively. Furthermore, the mean number of individuals collected per month from August to November were 107.61, 120.82, 50.13 and 58.5, respectively. Results of the community trends are presented in Figures 6–10. The differences in diversity indices [the Shannon Index (H), Shannon Evenness (E), Dominance Index (c) and Species Richness Index] were computed and compared for each month. These indices are discussed in relation to the abundance of inflorescence for the duration of the study.

The month of November showed the highest diversity index at 2.03, followed by September at 1.52, October at 1.40 and by the lowest, August at 1.30. The evenness follows a similar trend having 0.80, 0.54, 0.51 and 0.50, respectively. However, the dominance index

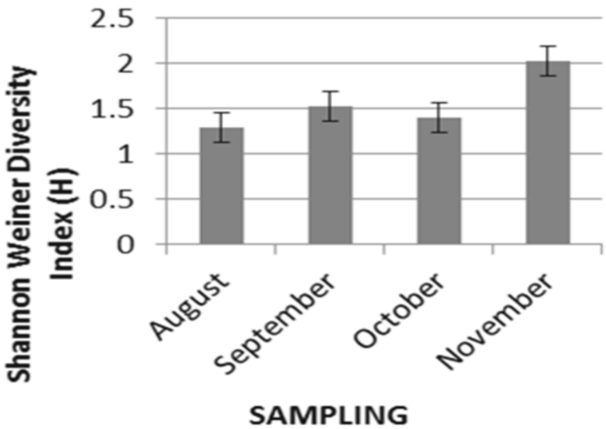

Fig. 6. Trends in the diversity of species attracted to nipa [*Nypa fruticans* (Wurmb.) Thunberg] inflorescence.

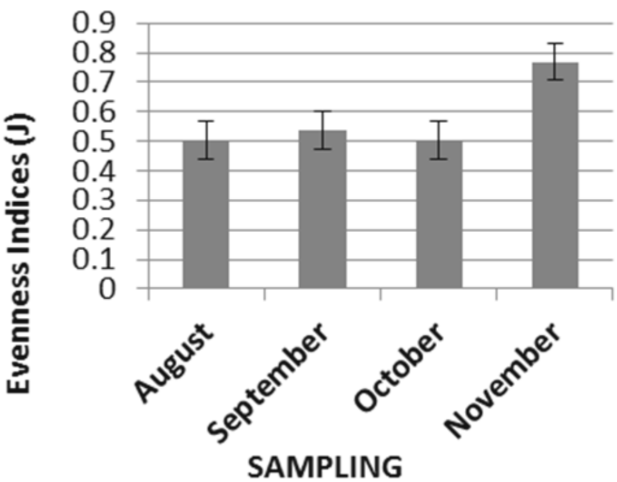

Fig. 7. Trends in the species evenness of arthropods attracted to nipa [*Nypa fruticans* (Wurmb.) Thunberg] inflorescence.

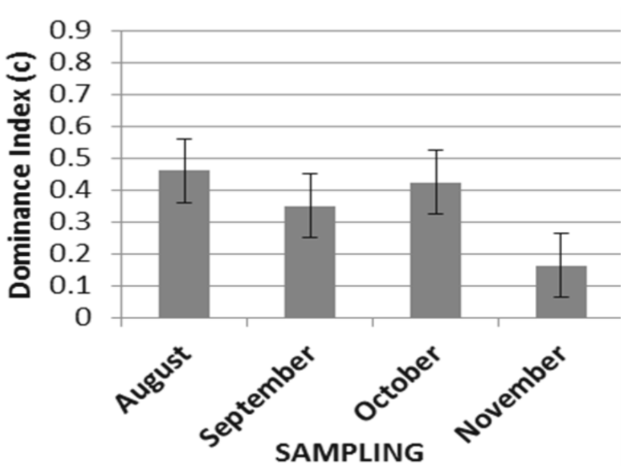

Fig. 8. Trends in the relative dominance of insects attracted to nipa [*Nypa fruticans* (Wurmb.) Thunberg] inflorescence.

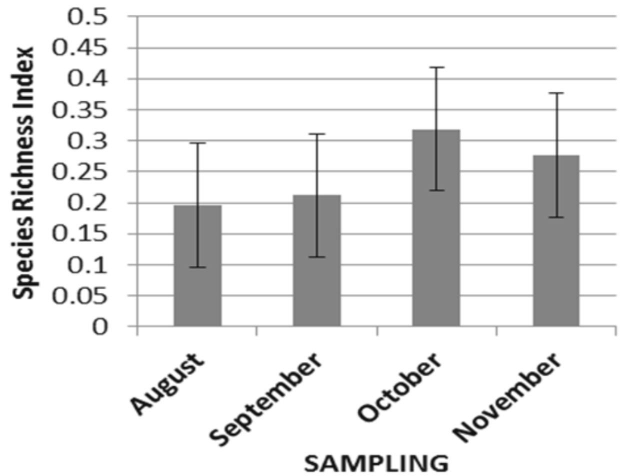

Fig. 9. Trends in the species richness of arthropods attracted to nipa [*Nypa fruticans* (Wurmb.) Thunberg] inflorescence.

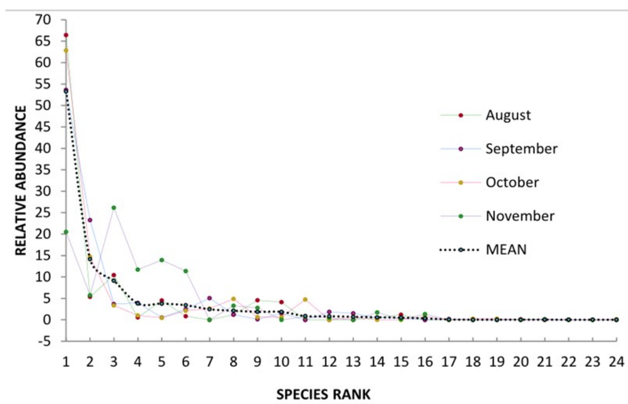

Fig. 10. Rank-abundance curve of arthropods visiting nipa [*Nypa fruticans* (Wurmb.) Thunberg] inflorescence.

showed that there are more dominant species in August (0.46), followed by October (0.43), September (0.35) and November (0.16). The highest numerical species richness was recorded in October (0.32), followed by November (0.28), September (0.21) and August (0.20).

Results showed ample evidence of increasing diversity and evenness of distribution for species of insects attracted to the inflorescence of nipa, which can be attributed to the abundance of inflorescence during the sampling period. The flowering period of nipa is the whole year round but peaks through the months of August to September. Furthermore, the inflorescence is a specialized type of resource and floral parts, and development of nipa inflorescence is a form of adaptation to pollinating insects (Uhl and Moore 1977). Therefore, insect groups that provide a positive impact on the reproductive success of the plant species are more favored by the inflorescence.

On the other hand, insects that are more favored or consistently rewarded by the plants are more frequent and dominant in the inflorescence. Moreover, the dominance index trend decreases from August to November, indicating that species distribution approaches more evenness. The presence of high dominance and the degree of unevenness in species distribution provide valuable data which suggest that a group or a few groups of insects are dominant in the sample set. Consequently, these dominant species are the likely pollinators of nipa based on their feeding activity and the evidence that they become covered with pollen.

Relative Abundance and Dominance

The relative abundance and the dominant species of insects in the study area are summarized in Table 2. The number of species varied from time to time, with the month of November having the most number of species (6), followed by August (33), September (3), and October (2). In terms of dominance throughout the sampling period, three species stood out: sap beetles (*Epuraea* sp.), rove beetles (Staphylinidae) and black earwigs (Chelisochidae). However, only *Epuraea* sp. and Staphylinidae were consistently present.

The differences in relative dominance for arthropods visiting the nipa inflorescence are shown in Figure 10. The most abundant species is *Epuraea* sp., followed by Staphylinidae, Chelisochidae, Curculionidae (Rhyncoporini), Curculionidae (Apionini), *Drosophila hypocausta*, *Drosophila* sp., *Haptorcus* sp. and other insects.

Pollination in *Nypa fruticans*

A diversity survey was conducted to determine potential pollinators of nipa. Among the insects collected, some groups were consistently observed visiting the inflorescence (Table 3). This observation provided evidence for the inference that the nipa inflorescence serves as feeding-burrowing site for the larvae of small fruit flies and vinegar flies and that drosophiline flies are pollinating the nipa plant in return for food (pollen and sap), shelter and oviposition site.

In Table 3, seven species from the families of Nitidulidae, Curculionidae and Drosophilidae are distinguished as potential pollinators. These families of insects have already been discussed by Henderson (1986) and Barford et al. (2011) as pollinators in other palms. Sap beetles, particularly from the genera *Epuraea* and *Mystrops*, are often recorded as pollinators in other palms (Barford et al. 2011). Curculionidae have been determined by Barford et al. (2011) as the most common beetle visitors in palm inflorescences. Nonetheless, drosophiline flies have been reported earlier by Essig (1973) as potential pollinators of nipa palms. Recently, Barford et al. (2011) concluded that fruit flies are pervasive on palm inflorescences and that they are generalist visitors in all kinds of flowers. During observation, fruit flies have been observed to visit mostly the decaying inflorescences. However, the observation that drosophilid flies have pollen adhering to their body segments does not contribute sufficient evidence to conclude that these flies are transferring pollen to the stigma and visiting the locular canals of the pistillate flowers. The fact that fruit flies are present in large numbers does not measure pollination capability. However, the role of fruit flies in nipa pollination cannot be completely eliminated in this study even if the fruit flies were given the status as less important pollinators.

On the other hand, *Epuraea* (sap beetles) were consistent insect visitors in great numbers to palm inflorescences. Furthermore, *Epuraea* sp. were observed to be present also in the pistillate flowers. In this study, the mechanism by which *Epuraea* sp. pollinate the nipa inflorescences is through the sap beetles crawling from the staminate spikes to the pistillate head in the essence of looking for food. An advantage of sap beetles over drosophiline flies is that these beetles crawl on the inflorescence and are small enough to enter the locular canals of the inflorescence. On the other hand, drosophiline flies feed and graze only in the staminate flowers and on detached pollen in the bracts. Furthermore, the proboscis of drosophiline flies does not reach the locular canals.

Weevils are given more importance than other insects in the pollination of nipa palms. An advantage of weevils over the other potential pollinators is their elongated snout for procuring food sources from crevices of flowers. Based on field observation, weevils from the tribe Apionini visit the locular canals. Apionini visitors are also present in the male spikes of the inflorescences. Furthermore, the weevils visiting the locular canals developed a pattern of visiting the canal as well as the staminate spikes because of rewards available in the form of pollen, soft tissues and possibly the gelatinous material found in locular canals.

Weevils from the tribe Rhynchoporini are also important insect visitors in the nipa inflorescence. Rhynchoporini species observed in the inflorescence were covered with a significant amount of pollen in their bodies, especially the elongated snout. An advantage of these insect visitors is their larger size than that of the Apionini visitors. Moreover, the presence of the slender snouts is an advantage over *Epuraea* visitors. Thus, Rhynchoporini visitors are considered more important in the pollination of *Nypa fruticans*.

Table 2. Relative dominance of the insect visitors of nipa inflorescence[1].

Family/Genus	Sampling				Total
	August	September	October	November	
Chelisochidae	10.44	(3.70)	(3.37)	26.13	9.12
Curculinidae (Apionini)		(3.94)		11.72	(3.80)
Curculionidae (Rhynchoporini)	(4.50)			13.92	(3.78)
Nitidulidae (*Epuraea* sp.)	66.40	53.65	62.84	20.51	53.27
Nitidulidae (*Haptorcus* sp.)			(4.86)	(3.30)	(2.13)
Staphylinidae	5.36	23.27	14.71	5.74	14.15
Drosophilidae (*D. hypocausta*)		(2.48)	(2.12)	11.36	(3.41)
Drosophilidae (*D. (Sophopora*)	(4.57)			(2.81)	
Drosophilidae (*D.* sp.)		5.06	(2.62)		(2.46)
Formicidae (*Tapinoma* sp.)			(4.74)		
Lygaeidae	(4.15)				
Total species (Dominant)	3	3	2	6	3
Total Species (Subdominant)	3	3	5	2	5

[1]Entries with parenthetical notation "( )" are subdominant species [<5.0]

Table 3. Functional guild of insect visitors in nipa palm [*Nypa fruticans* (Wurmb.) Thunberg].

Order	Taxa	Functional Guild
Dermaptera	Chelisochidae	Predator
Coleoptera	Staphylinidae	Predator
	Nitidulidae (*Epuraea* sp.)	Pollinator
	Nitidulidae (*Haptorcus* sp.)	Pollinator
	Curculionidae (Rhynchoporini)	Pollinator
	Curculionidae (Apionini)	Pollinator
Diptera	Drosophilidae(*Drosophila hypocausta*)	Pollinator
	Drosophilidae (*Drosophila (Sophopora)* sp.)	Pollinator
	Drosophilidae (*Drosophila* sp. 1)	Pollinator
	Muscidae	Pests

CONCLUSION

The insect visitors were determined through field observations and insect collection. The abundance and activity of these insects were recorded and analyzed with reference to pollination. Likewise, diversity indices were computed and analyzed to identify the most dominant insect visitors. The interaction of the insects with the flower hosts was described in relation to pollination.

This study found four new species of insects that are potentially pollinating the nipa inflorescence. Two species of weevils (Curculionidae) and two species of sap beetles (Nitidulidae) are considered frequent visitors to the nipa inflorescence. Furthermore, they were abundant during the insect visitation as well as in the insect collection. From this study, a few facts are clear:

1. Curculionidae, Nitidulidae, and Drosophilidae were numerous in the inflorescence and they had pollen stuck to their bodies.
2. Curculionidae have elongated snouts which are fitted to the locular canals of the pistillate flowers and these insects were observed visiting the pistillate flowers.
3. Nitidulidae (*Epurea* sp.) were present in large numbers and gregariously grazed on the inflorescence; because sap beetles are crawling and small insects, they can maneuver to enter the locular canals of the pistillate flower.
4. Drosophilidae were also present in large numbers but these insects were grazing only on the surface of the inflorescence.
5. The giant honeybees, in the essence of collecting pollen from the conspicuous staminate spikes, drive away smaller visitors such as the Nitidulidae and Drosophilidae to leave the inflorescence and look for another to feed upon.

From these observations, we derive the generalization that pollination of nipa palms occurs through the mediation of insect visitors from the families Curculionidae, Nitidulidae and Drosophilidae. More importantly, the Curculionidae and Nitidulidae are given more attention as the potential pollinators. Therefore, nipa pollination can be considered entomophilous in the general sense with the predominance of cantharophily as the pollination syndrome.

We recommend that observations be done on the female flower to determine its receptivity and to test whether or not self-pollination is possible for nipa. Another way of testing whether nipa plants are self-pollinated or not is through bagging experiments to exclude insect visitors to the inflorescence and to measure the number of fruit set as the measurement of successful pollination. Future studies may be conducted to ascertain whether self-pollination is happening or not on the nipa inflorescence. Furthermore, night-time observations are needed to assess the activity of nocturnal insects observed during the conduct of the study.

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