Plant-Pollinator Networks in Mixed Fruit Orchards in Southern Thailand

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ABSTRACT

Currently, human activities causing habitat changes impact biodiversity worldwide. The connectivity is one of the landscape properties helping individuals disperse across space. The lack of landscape connectivity can also interfere plant-animal interaction, such as pollination. Many pollination studies have focused on the impact of proximity to natural habitats on the pollination ecology or reproductive success of single crop species in system. However, each species in the same landscape might have different reaction to landscape change, it is very important to understand the interaction in the whole community. In my thesis I use pollination network approach to study pollination and investigated number of fruit set in three crop species, rambutan, durian, and mango in 10 pairs of mixed fruit orchards, near (<1 km) and far (>7 km) from forest edge. The network from sites near forest edge showed higher connectance, number of links per species, robustness after removing animal species, linkage density, and interaction evenness, and the number of fruits set per inflorescence in rambutan sites near forest was significantly higher. However, the species strength of bat in pollination network was not affected by forest proximity. Similarly, distance to forest played no role for number of fruits set in durian and mango. The dominant flower visitor to durian and mango were fruit bats and flies, respectively. The number of fruit set in durian was negatively affected by distance to cave. This study provides empirical evidence that not only forest but also caves can act as a source of flower-visiting agents that provide pollination services to agricultural crops and underscore the importance of tropical rainforest and cave conservation for maintaining such services.

ชื่อวิทยานิพนธ์ การศึกษา Pollination network ในสวนผลไม้ผสมผสานในภาคใต้ของประเทศไทย
ผู้เขียน น.ส. เตือนจิต ศรีทองช่วย
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บทคัดย่อ

ในปัจจุบัน มนุษย์เป็นสาเหตุของการเปลี่ยนแปลงของพื้นที่ซึ่งส่งผลต่อความหลากหลายทางชีวภาพ ความต่อเนื่องของพื้นที่เป็นคุณสมบัติอย่างหนึ่งที่ช่วยให้สิ่งมีชีวิตสามารถเคลื่อนที่ระหว่างพื้นที่ได้ดังนั้นการที่พื้นที่ขาดการเชื่อมต่อทำให้สัตว์ต่างๆ ร่วมทั้งสัตว์ที่ช่วยในการถ่ายละอองเรณูไม่สามารถเคลื่อนที่ระหว่างพื้นที่ได้ การศึกษานิเวศวิทยาการถ่ายละอองเรณูส่วนมากทำการศึกษาผลกระทบของระยะทางจากป่าต่อการถ่ายละอองเรณูในพืชเพียงชนิดเดียวในแต่ละบริเวณ อย่างไรก็ตาม พืชแต่ละชนิดในบริเวณเดียวกันอาจตอบสนองต่อการเปลี่ยนแปลงของพื้นที่ต่างกันดังนั้นจึงจำเป็นอย่างยิ่งที่จะต้องศึกษาการถ่ายละอองเรณูของพืชทุกชนิดในพื้นที่เดียวกัน การศึกษาครั้งนี้ศึกษาโดยใช้ pollination network และ ศึกษาการติดผลของพืชเศรษฐกิจ สามชนิด คือ เงาะ ทุเรียน มะม่วง ในสวนผลไม้ผสมผสานบริเวณใกล้ป่า (ระยะทางน้อยกว่า 1 กม จากป่า) จำนวน 10 สวน และบริเวณไกลป่า (ระยะทางไกลกว่า 7 กม จากป่า) จำนวน 10 สวน พบว่า pollination network จากสวนที่ใกล้ป่ามีค่า connectance, number of links per species, robustness, linkage density, และ interaction evenness รวมทั้งการติดผลของเงาะสูงกว่าสวนที่ไกลป่า แต่ species strength ของค้างคาวจากใน pollination network ไม่ได้รับผลกระทบจากระยะทางจากป่า เช่นเดียวกันกับการตติดผลของทุเรียนและมะม่วง เนื่องจากทุเรียนมีค้างคาวเป็นสัตว์ช่วยพาละอองเรณูจึงพบว่าการติดผลของทุเรียนเป็นไปในทางตรงข้ามกับระยะทางจากถ้ำซึ่งเป็นที่อยู่ของค้างคาว การศึกษาในครั้งนี้ช่วยยืนยันว่าไม่เฉพาะแค่ป่าที่เป็นที่อยู่ของสัตว์พาหะช่วยถ่ายละอองเรณูแต่ยังรวมถึงถ้ำซึ่งเป็นที่อยู่ของค้างคาวอีกด้วย

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Tuanjit Sritongchuay

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CHAPTER 1

GENERAL INTRODUCTION

1.1 Introduction

Pollination event occurs when pollen taken from anthers of a flower are deposited to the stigma by wind, water, insects, birds, or mammals. Most of tree species in tropic are self-incompatible (Kress & Beach 1994) and almost all of them rely on animals for pollination (Bawa 1990). Without interaction, plants that rely on animal pollination cannot receive the pollination service they need to produce seed, thus pollinators must meet in space (and time) to interact with plant. Plants and pollinators cannot interact because spatial distributions are not overlap, for instance, spatial distribution of ranges at much larger geographic scales (Jordano et al 2003), habitat loss and fragmentation.

The original forest ecosystems have been changed into heterogeneous mosaic of forest remnants by agricultural and urban expansion (Lambin et al 2001) and those heterogeneous forests are the important sources of pollinator as well as sustaining pollinator population to crops because the forests provide foraging, nesting, and nesting materials sites (Steffan-Dewenter 2003a; Kremen et al. 2004; Greenleaf and Kremen 2006a;Gardner et al. 2009, Carvalheiro et al. 2010, Melo et al. 2013). Many studies have found that the distance from forest have a negative impact on pollinator abundance and richness in both tropical ecosystems (De Marco and Coelho 2004; Blanche et al. 2006; Chacoff and Aizen 2006, Heard & Exley 1994; Klein, Steffan-Dewenter & Tscharntke 2003 a, b; Blanche & Cunningham 2005; Blanche, Ludwig & Cunningham 2006) and in temperate ecosystems (Taki et al. 2007; Watson et al.

2011). Plant-pollinator interactions often result in reproductive success of plants so the limit of visiting frequency can lead to pollen limitation and plant reproduction (Harris and Johnson 2004, Gomez et al 2010). Unfortunately, what we known about pollination mostly are about plant and insect interaction. There are some economic plants whose pollination relies on the cave-dwelling nectar bats such as durian (*Durio zibethinus*) and both insects and bats such as bitter bean (*Parkia* sp.). Thus, proximity to caves might affect that plant pollination. Only a few studies have evaluated the consequence of forest fragmentation on the relationship between bats and plant reproductive success (Quesada *et al*. 2003; Quesada *et al*. 2004). However no studies have yet directly evaluated the effect of distance to caves on reproductive success of chiropterophilous plants. Moreover most of those pollination studies have considered on one or few plants in a system. For conservation of many species, it is important to understand plant-pollinator interaction in the level of entire ecosystem.

The researchers have started to develop plant-pollinator interaction knowledge from studying on single species to new understanding by applying whole community approaches both qualitatively (Arroyo *et al.* 1982, Motten 1986) and quantitatively (Memmott 1999, Gibson *et al.* 2006). Some community studies overlook the detailed biology of specific interactions, such as general patterns in the structure of plant–pollinator communities (Olesen & Jordano 2002, Jordano *et al.* 2006), including the highly asymmetrical network organization (e.g. Olesen and Jordano, 2002; Bascompte et al., 2003; Blüthgen et al., 2006), and nestedness (Bascompte et al., 2006). This pattern increases network robustness against natural spatial and temporal changes in environmental conditions (Wolda, 1988; Tylianakis et al., 2005). However, the decline of generalist pollinators, which interact with more plant species, could trigger cascades of declines among specialist plant species to which pollinators are linked (Memmott et al., 2004; Pauw, 2007). Factors that may affect the pollination network structure are phenotype, demography, distribution, and dispersal ability (Vazquez et al 2009). Habitat loss and fragmentation can also isolate pollinator populations and disrupt the structure of plant-pollinator interaction and even low levels of habitat destruction can cause species loss (Fortuna and Bascompte 2006). Since study of consequences of proximity to the pollinator sources on plant–pollinator networks, especially from tropical area still lack, understanding how pollinators and their plants react to increasing of distance to the pollinator sources is important for the conservation of biodiversity and related ecosystem services such as pollination.

In this thesis, I compare plant–animal interactions from mixed fruit orchards in different distance (near vs far) from forest edge. I chose this system because mixed fruit orchards are very unique in South East Asia and low-intensify orchards are often comprised of multiple plant species in different stories, as well as receive minimal disturbance from pesticide use.

1.2 Literature reviews

The importance of network structure

According to ecological network, we need to understand network structure because the network structure may affect the ecosystem stability (Neutel et al., 2002, Krause et al., 2003, McCann et al., 2005). Ecosystem stability is defined concerning resistance to secondary extinctions following one species successively removed from the web (Sole and Montoya, 2001, Dunne et al., 2002, Memmott, et al 2004). For example in the study of Biesmeijer, et al (2006) found that the decline of pollinators following by the declines in plants that rely on them. Moreover the webs quickly break into disconnected sub-webs after removing the plants or pollinators from network (Sole and Montoya, 2001, Montoya et al., 2006).

Patterns of mutualistic network structure

These are parameters using to measure the network structure:

1. Interaction diversity.

Interaction diversity is the number of interactions (links) in the network, which diversity is also measured in terms of number of species in the network (Tylianakis, et. al. 2010). Interaction diversity is important character in network because the higher interaction diversity may increase ecosystem processes. For example, in pollination system from previous study of Hoehn et al (2008) shows the seed set increased strongly with bee species richness. The interaction diversity can refer to interaction richness (number of links in network), link density, or connectance.

2. Nestedness.

Nestedness is the pattern of interaction which the second most generalized pollinator interact with subset of plant species visited by the most generalized, the third most generalized interact with subset of plant species visited by second generalized species, and so on (Memmott, 2004; Bascompte, and Jordano, 2007). A nested pattern of interaction is necessarily asymmetric specialization between plants and pollinators which means the most specialists, which are rare species and show less interaction, do not have specialized interaction partners (Bascompte, et al., 2003, Vazquez and Aizen, 2004) Thus, nestedness in the interaction network is the important pattern due to nestedness provides the tolerance on second extinction. For example, if the most specialist pollinator goes extinct from nestednes network, the plant species that is pollinated by that animal can still be pollinated by other more generalist species (Memmott et al., 2004, and Bascompte et al, 2006)

3. Distributions and patterns of interaction strength.

Pattern of interaction strength (dependences) can be weak and strong interaction. From previous studies most of pollination networks have the right skew on frequency distribution of interaction strength, which there are several weak dependences and a few strong interactions (Paine, 1980, Wootton, 1997, and Bascompte et al. 2006).

We have to consider about distribution and patterns of interaction strength because in strong dependence pairwise species, a decrease in plant abundance will more affect to changes in population densities of animal species they linked to (Tylianakis et al., 2010). However, the dependence of plant and animal is asymmetry, if plant had a strong dependence on animal, then that animal depend on that plant much weaker than expected by chance (Bascompte et al., 2006, and Stang et al., 2007). These weak and asymmetric dependences in mutualistic networks make the entire network more resistant to secondary extinctions (Bascompte et al., 2006)

4. Compartmentalisation and modularity

Compartments (modules) are the subsets of an interaction network which species within a module interact more tightly with one another than they are to species in other modules. The important species in modular network is module hub, which highly connected species link to many species within the same module (Krause et al

2003, Olesen et al., 2007). A compartmentalized structure can derive from restrictions to species ranges (Lewinsohn et al., 2006), and pollination syndrome and phenology (Dicks et al., 2002). The interaction between plants and their potentially pollinators is expected to find compartmentalization because of the tendency of zoophilous plants to fall into "syndromes" associated with types of visitor (Faegri and Pijl, 1979). However, in the modular network, several modules can be linked by connector species, which highly connected species linked to many species in different modules. Understanding structure of ecological network particularly, compartment is essential part of study of biodiversity and its responses to disturbances because from previous study disturbance are expected to spread more slowly through a modular than non-modular structure (Olesen et al., 2007). Moreover, the network consequences of species extinctions depend on species role, for example, an extinction of a module hub may cause its module to fragment without impact on other modules (Prado and Lewinsohn, 2004). Hence, to identify the role of species in the modular networks is important to conservation.

5. Interaction evenness

Interaction evenness is a measure of different pathways of interaction in network. From previous study, interaction evenness of parasitoid-host networks tend to decline with more disturbed habitats (Albrecht et al., 2007, Tylianakis et al., 2007), but interaction evenness in multitrophic webs (plant-herbivore-parasitoid) was affected by perturbation (Heleno et al 2009). Although interaction evenness is commonly applied to use in trophic interaction network (food web), it is also applicable to other interspecific interaction such as pollination network (Geslin et al 2013).

Processes behind mutualistic network patterns

Vazquez et al. (2009) has mentioned that both interaction neutrality and trait matching result in true network structure. Interaction neutrality and trait matching are affected by community structure (species composition, richness and relative abundance). For example from previous studies in plant-pollinator, plant-seed disperser network, the mean number of links per species decreases, whereas, the nestedness, and degree asymmetry increases when the species richness increases (Bascompte et al., 2003, Montoya and Sole, 2003, and Vazquez and Aizen, 2004). In addition to species richness, the relative abundance is also the one factor that influences on network structure, for instance, nestedness, degree and strength asymmetry (Dupont et al. 2003, Vazquez and Aizen, 2004). In food web, the interaction diversity increases when the insect abundance is high (Tylianakis et al. 2007). The main factor influencing on community structure is spatio-temporal distribution (Burkle and Alarcon 2011). The distance from forest might be the spatial variation causing the different network pattern, however, from the past; there is no study about the effect of forest edge on pollination network structure.

1.3 Concept and outline of the thesis

The general aim of my thesis is to investigate the plant-pollinator interactions in mixed fruit orchards at near and far from forest edge, and caves. In order to address this issue, I employed pollination network approach which developed from focusing on single plant species to habitat approaches. My work presents finding from depth field experiments on few plant species, to community-wide study of entire plant-pollinator systems. Specifically, my thesis contains the following chapters:

Chapter 2 compares community data on pollination network from orchards at near and far from forest edge

Chapter 3 contain observational and experimental data on the pollination ecology and fruit set of three crops species, rambutan, durian and mango. This chapter breaks new in ground in bat pollination ecology by presenting the impact of distance to cave on bat visit frequency and reproductive success of durian, bat pollinated plant.

Each chapter is written in manuscript format, which will lead to some overlap between them.

1.4 Study area

Southern Thailand where the mixed fruit orchard is typical ranges from , 6° 20'to 8°20'S and 99°40' to 110°00'E. South-west monsoon which bring rainy season to west part of the south, start from May and last into October while North-east, result in rainy season in east part arrive from November to April. The dry season is very shot in the South because of the proximity of the sea to all part of the Malay Peninsula. This study was conducted in 20 mixed fruit orchards in Songkhla, Phattalung, and Nakhon Si Thammarat Fig 1.1 These orchards are formed mostly by *Sandoricum Koetjape, Musa sapientum, Nephelium lappaceum, Artocarpus integer, Durio zibethinus, Archidendron jiringa, Capsicum frutescens, Cocos nucifera, Garcinia mangostana, Lansium domesticum, Azadirachata indica, Parkia speciosa,* a few native trees remained such as *Fragraea fragrans,*

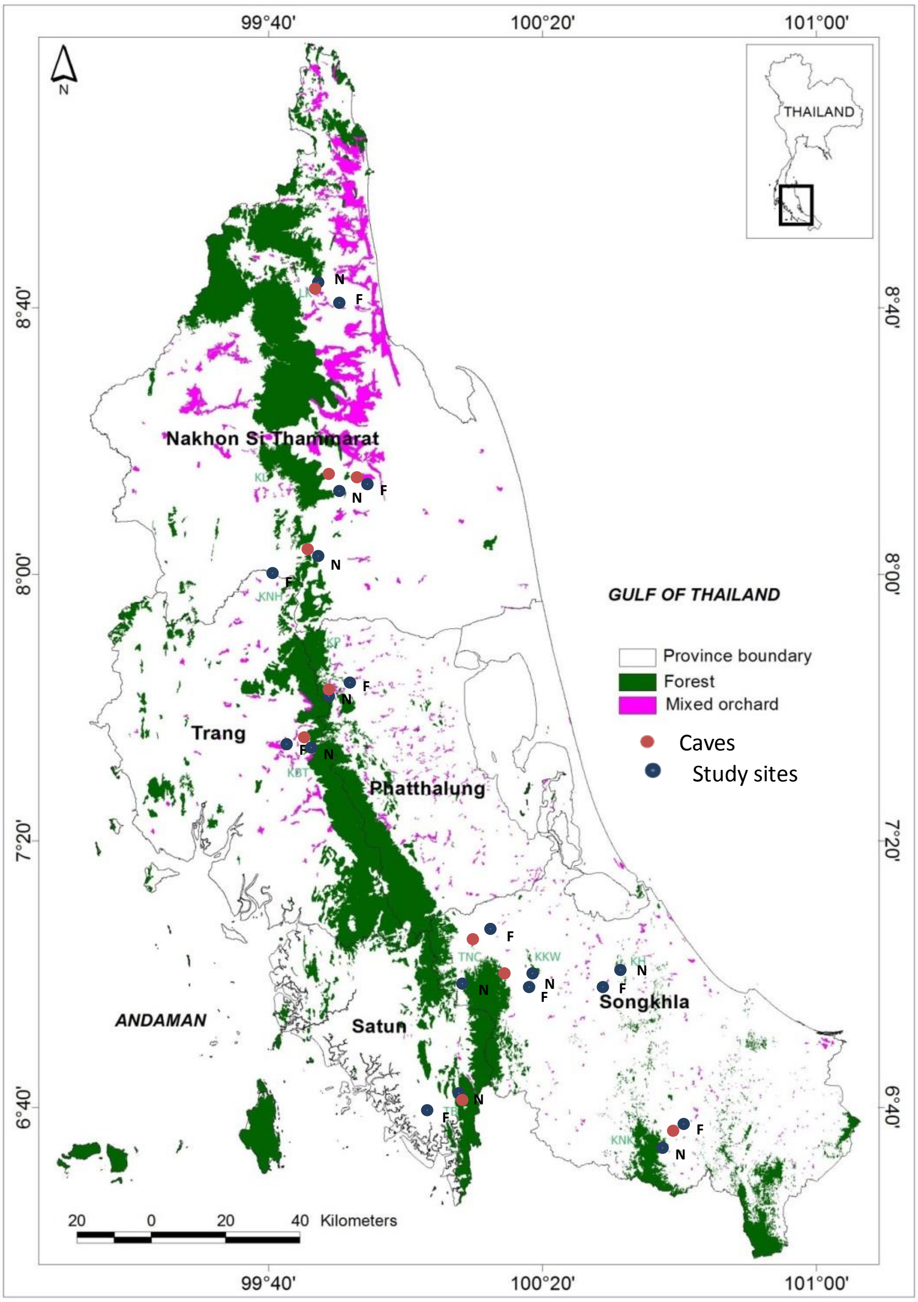

Figure 1.1 Map of study site, visitors and fruit set were sample from 20 orchards from varying distances from 10 forest patches.

Table 1.1 Species of plants found in all study site stations

No	**Scientific name**	**Type**	**Family**
1	*Sandoricum koetjape* (Burm.f.) Merr.	Tree	Meliaceae
2	*Musa sapientum* L.	Shrub	Musaceae
3	*Licuala paludosa* Griff.	Shrub	Palmae
4	*Theobroma cacao* L.	Tree	Sterculiaceae
5	*Artocarpus heterophyllus* Lam.	Tree	Moraceae
6	*Alpinia galanga* (L.) Willd.	Shrub	Zingiberaceae
7	*Zingiber officinale* Rosc.	Shrub	Zingiberaceae
8	*Cassia siamea* Lamk.	Tree	Leguminosae
9	*Nephelium lappaceum* L.	Tree	Sapindaceae
10	*Barringtonia acutangula* (L.) Gaerth.	Tree	Lecythidaceae
11	*Artocarpus integer* (Thunb.) Merr.	Tree	Moraceae
12	*Syzygium malaccense* Merr & Perry	Tree	Myrtaceae
13	*Garcinia cowa* Roxb.	Tree	Guttiferae
14		Tree	Lauraceae
15	*Etlingera elatior* (Jack.) R.M. Smith.	Shrub	Zingiberaceae
16	*Flacourtia indica* (Burm. F.) Merr.	Tree	Tiliaceae
17	*Dipterocapus sp.*	Tree	Dipterocarpaceae
18	*Averrhoa bilimbi* L.	Tree	Oxalidaceae
19	*Alstonia scholaris* (L.) R. Br.	Tree	Apocynaceae
20		Tree	Leguminosae
21	*Fragraea fragrans* Roxd.	Tree	Gentianaceae
22	*Durio zibethinus* L.	Tree	Malvaceae (Bombacaceae)
23	*Alstonia macrophylla* Wall. Ex. G. Don	Tree	Apocynaceae
24	*Annona squamosa* L.	Shrub	Annonaceae
25	*Ceiba pentandra* (L.) Gaerth.	Tree	Malvaceae (Bombacaceae)

26	*Archidendron jiringa* (Jack) Nielsen.	Tree	Fabacea
27		Shrub	Poaceae
28	*Psidium guajava* L.	Tree	Myrtaceae
29	*Capsicum frutescens* L.	Shrub	Solanaceae
30	*Microcos tomentosa* Smith.	Tree	Tiliaceae
31	*Oroxylum indicum* Vent.	Tree	Bignoniaceae
32	*Citrus hystrix* DC.	Tree	Rutaceae
33	*Spondias mombin* L.	Tree	Anacadiaceae
34	*Tamarindus indica* L.	Tree	Fabacea
35	*Solanum torvum* SW.	Shrub	Solanaceae
36	*Dillenia indica* L.	Tree	Dilleniaceae
37	*Citrus aurantifolia* Swingle.	Shrub	Rutaceae
38	*Bouea microphylla* Griff.	Tree	Anacadiaceae
39	*Averrhoa carambola* L.	Tree	OXALIDACEAE
40	*Cocos nucifera* L.	Tree	Arecaceae
41	*Baccaurea ramiflora* Lour.	Tree	Phyllanthaceae
42	*Mangifera indica* L.	Tree	Anacadiaceae
43	*Mangifera foetida* Lour.	Tree	Anacadiaceae
44	*Carica papaya* L.	Shrub	Caricaceae
45	*Garcinia mangostana* L.	Tree	Clusiaceae
46	*Antidesma ghaesembilla* Gaertn.	Shrub	Euphorbiaceae
47	*Glochidion Perakense* Hook. f.	Shrub	Euphorbiaceae
48	*Morinda citrifolia*	Tree	Rubiaceae
49	*Lansium domesticum* L.	Tree	Meliaceae
50	*Manilkara zapota* (L.) Van Royen.	Shrub	Sapotaceae
51	*Lansium domesticum* Corr.	Tree	Meliaceae
52	*Duabanga grandiflora* Walp.	Tree	Sonneratiaceae
53	*Dimocarpus longan* Lour.	Tree	sapindaceae
54	*Citrus*	Shrub	Rutaceae
55	*Zalacca edulis* Reinw.	Shrub	Palmae
56	*Azadirachta indica* A. Juss.	Tree	Meliaceae

57	*Parkia speciosa* Hassk.	Tree	Fabacea
58	*Ananas comosus* (L.) Merr.	Shrub	Bromeliaceae
59	*Areca catechu* L.	Tree	Arecaceae
60	*Clausena cambodiana* Guill.	Shrub	Rutaceae
61	*Syzygium cumini* L.	Tree	Myrtaceae
62	*Clitoria ternatea* L.	Liana	Fabacea
	Total		

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CHAPTER 2

Forest proximity alters the structure of tropical pollination networks in mixed fruit orchards.

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Abstract

Habitat loss is the major cause of the current pollinator decline. The isolation from pollinator sources, forest patches or natural habitats, might affect on the crop pollinator community. While the negative effects of natural habitat proximity on the diversity of pollinators of a sigle crop have been reported, it is uncertain whether those schemes also alter the pollination network structure. Here we compared plant-pollinator interaction network structure in 10 pairs of mixed fruit orchards which are near (<1 km) and far (>7 km) from forest edge. Average number of visitor-flower interactions was higher at sites near to forest edge. Similarly, other network indices, including connectance, number of links per species, robustness after removing animal species, linkage density, and evenness were higher at sites near forest edge but nestedness were not significant different between both sites. Our results support that the proximity to forest edge affect on both the complexity and stability of pollination network structure.

Keywords: forest proximity, pollination network, robustness, evenness

2.1 Introduction

Landscape change caused by habitat loss and fragmentation by human activities are the problem for biodiversity and major cause of mutualism disruption (Pimm & Raven 2000, Ashworth et al 2004). Decreasing habitat availability at landscape level can isolate patches of suitable habitat, leading to reducing dispersal rates and changing the spatial distribution of resources (Holyoak et al 2005). Significant effects of landscape changes on the diversity, frequency and movement patterns of pollinators, mostly due to increased isolation of habitat patches have been detected (Greenleaf and Kremen, 2006, Brosi et al 2007, Zurbuchen et al 2010). Communities of plants and their pollinators, as well as the services they provide, can be highly dependent on the distance to natural habitats. The negative effects of forest habitat proximity on the pollination ecology, species richness and abundance of pollinators of a single crop species have been intensively considered (Kremen et al, 2002, Klein et al 2003, Ricketts, 2004, and Chacoff and Aizen, 2006). There are some plants, such as bitter bean (*Parkia* spp.), whose pollination relies on several groups of pollinator which their abundance may not affect by forest proximity. For these two plants, the cave-dwelling nectar bat, *Eonycteris spelaea*, is clearly a principal pollinator (Bumrungsri *et al*. 2008; 2009). Moreover, another cave dwelling frugivorous bat, *Rousettus* spp., also facultatively feed on nectar (Nathan et al 2005, Stewart & Dudash, subm) . Thus, proximity to forest might not affect on bat visit frequency whereas the proximity to cave will play an important role in this case. However, the knowledge about how natural habitat proximity can affect ecological interaction networks and plant-pollinator networks in particular in whole community is still lack and need to be highlighted.

In past decade, we have seen the studies of ecological networks including the pollination, parasitoid, seed dispersal networks which describe the interactions between species, the underlying structure of communities and the function and stability (Montoya, et al 2006). The pollination network analyses show many pattern, including, plant-pollinator interactions are asymmetric that if plant depend strongly on the animal, the animal will depend weakly on plant and vice versa (Vazquez and Aizen, 2004, Bluthgen et al 2006, Vazquez et al 2009) and nestedness which describes the interaction of specialist species are the subgroup of the species interacting with generalists (Bascompte et al 2003). Plant – pollinator interaction networks have many generalist interactions and few specialist interactions (Vazquez et al 2009). And some pollination networks also show compartmentalization, small subgroup of tightly interacted species (Dicks et al 2002, Olesen et al 2007). Network indices are useful in determining the pattern of pollination network under different environments. Indices such as web asymmetry and nestedness (Ings et al 2009) are important descriptors of network structure. Of several ecological network indices, network robustness [a measure of resistance to secondary extinctions following one species successively removed from the web (Sole and Montoya, 2001, Dunne et al., 2002, Memmott, et al 2004)] has been particular studied to understand the real threat of biodiversity loss to ecosystem service and functioning (Pocock et al 2012). Another important index is interaction evenness. The effect of perturbation on the interaction evenness varies in different ecological networks, for instance, the interaction evenness of parasitoid-host network decline in more disturbed habitats (Albrecht et al 2007, Tylianakis et al 2007), whereas interaction evenness in plant-herbivore-parasitoid multitrophic webs may not be affected by invasion (Heleno et al 2009). However, the studies of evenness in pollination network are still lacking. Other indices include interaction diversity which are linkage density and connectance; compartments, the subset of an interaction network; vulnerability.

The impacts of habitat change and loss are likely to have great effects within ecological networks, by simultaneously affect species across trophic levels (Memmott et al 2007, Tylianakis et al 2008). From previous study, habitat loss can affect to pollination network in many ways. More specifically species interaction are lost very dramatically beyond even low levels of habitat destruction (Fortuna and Bascompte 2006, Keitt, et al 2009). The connectance and nestedness tend to decrease with habitat destruction (Spiesman, and Inouye, 2013) and increase modularity (Spiesman, and Inouye, 2013). Not only habitat loss can cause the disruption of pollination interaction networks but also have the strong impact on networks stability (Pimm, 1979, Krause et al. 2003, McCann et al. 2005). When more than half of the most connected species is lost can cause a sudden and rapid collapse of the total strength of the networks (Kaiser-Bunbury et al. 2010).

Since tropical and subtropical plants-pollinator communities are extremely high species richness leading to the practical constraints, most of pollination networks have been studied in temperate, arctic or high altitude habitats. Most pollination studies in tropical areas have been focused on subset of community. Only a few studies collect data on reproductive of flowering plant species within the community in tropic (Kato, 1996, 2000, Momose et al., 1998, Kaiser-Bunbury et al, 2009). However, this is the first study that takes place in agricultural habitat in tropic.

To understand effect of forest proximity on plant-pollinator interaction, it is thus important to characterize the structure of pollination networks in mixed fruit orchards at both near and far from forest patches. We chose this system because low-intensify orchards are often comprised of multiple plant species in different stories, as well as receive minimal disturbance from pesticide use. Once constructed, we discuss the effect of forest proximity on the network structure. Here we use these quantitative metrics (connectance, web asymmetry, number of links per species, compartment, nestedness, robustness, vulnerability linkage density, interaction evenness, species strength of different bat groups). We hypothesize that the proximity to the forest edged will affect the pollination network structure

2.2 Materials and method

2.2.1 Study sites

Mixed fruit orchards are common in South East Asia traditional villages supplying products both for household use and local markets. The common size of orchard patches range from 300 m^2 to 1 km^2. Each orchard consists of multi-storied planted fruit or selected native species of trees, as well as herbs and shrubs and resembles a forest in structure and diversity. The best-known example in Thailand is at Ban Khiriwong village, Lan Saka District, Nakhon Si Thammarat Province, where fruit orchards or ‘suan-somrom’ have operated for over 100 years (Makarabhirom 1991; Juiprik 1997).The main fruit trees are durian (*Durio zibethinus*), bitter beans (*Parkia speciosa*), mangosteen (*Garcinia mangostana*), domestic jackfruit (*Arthocarpus integer*), longon (*Lansium domesticum*), rambutan (*Nephelium lappaceum*), mango (*Mangifera indica*).

The mixed fruit orchards are distributed among forest patches. The study took place from January 2012 to June 2013, in 20 mixed fruit orchards situated at varying distances from 10 forest patches in southern Thailand (Nakhon Si Thammarat, Phattalung, Trang, Satun and Songkhla provinces, 6°20'to 8°20'S and99°40' to 110° 00'E. These ten patches of tropical rain forest, ranged in area between 360 to 65,000 ha and occurred from 230 to 1090 m elevation. Five to twenty percent of these forested areas were deforested for agricultural purposes, including rubber, oil palm and fruit orchard. We used 1:133,400 scale photographic imagery from Landsat Thematic Mapper data with a geographic information system (ARC GIS 10.2) to create a map of land use and determine the forest patch size and distances of orchards to the forest edge and to caves.The proportion of forest fractions within 20 km radius in each site was determined. All study species, durian, rambutan, mango, were found in each study site. We selected the study sites based on these criteria; 1) they represent a mixed fruit orchard which mainly compound with more than 10 species of fruit with similar plant community characteristic such as Parkia, Durian, Rambutan, Mangosteen; 2) they are managed to be mixed fruit orchard more than 10 years because this age is long enough to find the flowers of plants which take long time to produce fruit, namely durian; 3) Due to the foraging range of various flower visitors, Wahala & Huang (2005) reported that mean of some stingless bees (*Trigona thoracica*) foraging range in disturbed area from forest edge is 1.973 km, whereas the mean foraging range of some bats are further for instance, 1.7 to 6.9 km. for *Rousettus* (Bonaccorso *et al*. 2014) and 6 km. for *Eonycteris spelaea* (Archarya *et al.* in press). We classified orchards as ‘near’ if they are< 1 km away from the nearest rain forest patch and as ‘far’ if they are >7 km away from rain forest. In each forest patch, one pair of near and far orchards without pesticide application was selected and these orchards were at least 10 km. from other pairs. Among the pollinators, the nectar bat, *Eonycteris spelaea*, has the longest average foraging range of 6 km from its roosting site. We therefore deemed sites spaced at 10 km as independent. Distance from each study orchard to caves where bats may roost ranged from 0.7 to 29 kms. The data of bat roosting caves (Bumrungsri 1997; http://www.thailandcaves.shepton.org.uk) were used.

2.2.2 Plant communities

In all study sites, we carried out 50 x 150 m plot in which we set up 5 parallel 150 m transect, at interval of 10 m. To determine plants species abundance, we surveyed the plant communities from January 2012 to June 2013 by recording every individual of all flowering species in the study areas every month. We counted the number of floral unit, including individual flower, and capitulum. We determined the mean number of flowers in capitulum from 20 capitula. We estimated the number of individuals of each plant species, and we calculated the total number of flowers by multiplying the number of individual plants with the mean number of open flowers in each plant.

2.2.3 Flowering phenology

Phenology is one of the important factors affecting how the web breaks up into compartments (Dicks et al., 2002) so phenological observations were perennial work conducted every two weeks in each study site from November 2011 to October 2012. The first flowering date, 10%, and 50% of flourishing dates were recorded. Observation was in the morning or in the afternoon from 5 plants in each study site. For trees, the observation will be taken from four sides, North, South, East, and West. Binocular was applied to count inflorescences or individual flowers.

2.2.4 Flower-visiting animals

To identify flower visitors and understand how the network of interactions change with the proximity to forest, flower visitors observations were conducted monthly from April 2012 to June 2013, in calm weather (i.e. sunny and without rain, temperature ranging from 31 º C to 38 º C). On each orchard, we observed flower visitors while walking on transect (5 x 150 m) within 50m x 150m plot, from 08h00 to 11h00 and again from 15h00 to 18h30, recording both visitor frequency and visitor richness. We only collect data on insects visiting the reproductive parts of the flower. Pollinator observations were focally conducted from four directions, North, South, East, and West on each plant species for 15-min observation sessions. The insects were collected by using net. Once insects captured in the net, they were transferred to a killing bottle, which contain ethyl acetate. The insect specimens were pinned while they are fresh by using stainless steel pins, after that the specimens were dried. The specimens were labeled about the date, site of collection and plant on which the insect was collected. The insects which are easy to identify such as butterfly were identified by using field guides but for unidentified specimens were identified by professional taxonomists (see Acknowledgements). Some of common insects that cannot be identified to species were group to morpho-types (Memmott and Godfray, 1993). To minimize error from misidentification, the stingless bees were identified into 4 morphotypes in different body length.

For the nocturnal pollinators, such as bats, moths, the night shot video cameras were set to record for 15 minutes in every hour. Bats also were surveyed by netting in every study sites in order to confirm bat species from camera traps. Mist nets were set as close as possible to the flowers of durian. Visiting bats were identified to species following *The mammals of Thailand and South-East Asia* (Francis, 2008) mainly from its external morphology and size. Bat were categorized into two groups, nectarivorous and frugi-nectarivorous following criteria in Stewart et al (2014).

2.2.5 Pollination networks

To determine the pollination network structure in each of 10 pairs of networks, pollination webs were represented as metrics, with lines (representing the plant species) and columns (representing the visiting animal morphotypes). The overall pollination network structures of entire season were computed by bipartite package implemented in the R (ver. 2.13.0, R Development Core Team 2011 http://www.R-project.org)**.** Quantitative pollination networks were illustrated as bipartite visitation graph (Dormann et al 2009). For each network we then calculated the number of plant species (*I*), animal species (*J*), the realized proportion of possible links or connectance (C = *L*/(*IJ*)), number of realized links in a network (*L*), mean number of links per species: sum of links divided by number of species, interaction evenness (the same method was used in Tylianakis et al (2007)), whose the calculation is similar to Shannon index, web asymmetry: balance between numbers in the two levels, compartment: number of subsets of the web which are not connected to another compartment, nestedness, species strength: sum of dependencies for each species, and robustness: calculate the area below the “secondary extinction” curve. We randomly removed plant and pollinators without replacement, where a species was considered to be extinct if it was left without plant host or animal pollinator, similar to Memmott et al (2004), and Dunne et al (2002).

2.2.6 Statistical analyses

The effect of distance to forest (near vs far) on the number of plant and animal species, stingless bee abundance and indices of pollination network including number of links per species, connectance, web asymmetry, number of compartments, nestedness, robustness, evenness, were examined by using paired t-test.

To compare the visitor species similarity in each pair of study sites we used the Jaccard coefficient ($S_J = a/(a + b + c)$, when a is the number of species found in both study sites, near and far from the forest edge whereas b and c are the number of animal species found only in near or far from forest respectively.

Two-way ANOVA was conducted to detect the variation between distance to the forest and the effect of bat groups on the species strength of bat in pollination network. The frequency of bat visitation were sum into each group before calculate species strength of two bat groups.

2.3 Results

2.3.1 Plant community

Sixty-one species of flowering plant were found in all study sites. The near forest sites contained from 30 to 42 flowering plant species and the far forest sites from 27 to 38 species. The number of plant species showed no consistent patterns in both study sites, two pairs of study site showed the number of plant species at study site that far from the forest higher than near sites, however, there was no significant difference in number of plants species in both sites (paired-samples t-test: t (9) = 1.514, $P = 0.164$). Thirty one plant species (50.8% of all plant species) flowered year round, 27 species (44.3%), flowered between March and May, and 3 species flowered between August and October. Both sites were dominated by a few common species. The majority of flowering species were *Musa sapientum* L. (Musaceae), *Nephelium lappaceum* L. (Sapindaceae), *Azadirachta indica* A. Juss. (Meliaceae), *Sandoricum koetjape* Merr. (Meliaceae). *Musa sapientum* was also the species visited by nocturnal pollinators, including nectarivorous and fruit bats.

2.3.2 Flower-visiting animals

Overall, there were 325 animal species visiting flowers from 59 families within 8 invertebrate and 2 vertebrate orders. Study sites that near to the forest showed significantly higher species number of animals (paired-samples t-test: t (9) = 13.10, *P* <0.001). The Hymenoptera in our focal pollination networks perform key pollinator of both sites that near and far from forest, and within this order, 32 species belonged to the family Apidae. The stingless bees are the most abundant flower visitors in both study sites, accounting for 14.24% - 22.49 % in near forest sites and 12.44% - 15.5% in far forest sites. Stingless bees were significantly higher abundance at the sites near forest (Mean ± SD = 1660.8 ± 370.26) than sites far from forest (Mean ± SD = 987.7 ± 95.73, paired-samples t-test: t (9) = 6.80, *P* <0.001). Stingless bees interacted with 16 to 23 plant species in near forest sites and 14 to 25 species at far forest sites. During the nocturnal observation, we found 32 pollinator species visiting to total of 5 species of plant. Eight species of bat were found visiting to those plant species. Bats contributed to 0.2% to 0.4% of all visits at near forest sites and 0.3% to 0.8% at far forest sites. Three species of bird (*Cinnyris jugularis, Anthreptes malacensis, Arachnothera longirostra*) interacted with 6 plant species. The species of visitors in each pair from study site near and far from forest were ranging from 44% to 55.7 % similar to each other.

2.3.3 Pollination network structure

We found highly significant differences in pollination network structure (connectance, number of links per species, robustness after removing animal species, linkage density, and evenness) between both sites, however no significant differences of mean quantitative nestedness were detected between two sites (paired t-test, Table 2.1, Fig. 2.1). For robustness, random removal of pollinators leaded to a decline of plant species after 80% - 90% of all pollinator species had been removed (Fig. 2.2). The two-way ANOVA detected that the species strength of bat significantly higher in the pollination networks that far from forest edge and the nectarivorous bat show significantly higher species strength than frugi-nectarivorous bat (Table 2.2, Fig. 2.3)

2.4 Discussion

2.4.1 Pollinators

In our study, Hymenopterans (Apoidea), especially stingless bees were the most abundant and highly linked flower visitors. Bees have been ubiquitously known as potential pollinators of both crop and wild plant species (Klein et al 2007, Ollerton et al 2011, Garibaldi et al 2013). We suggest that stingless bees are keystone pollinator species for our pollination network, as keystone species is defined for species that are relatively more important to maintain community structure, and in network theory, the network collapse when we remove the most generalist pollinator (Memmott et al, 2004, Pocock et al 2012)

The stingless bees showed higher visitation frequency and more highly connected at the close forest sites compared with far forest sites. Similarly, sampling bees in Indonesian agroforestry systems detected a decrease in richness and abundance of social bees (Meliponini and Apini e.g. stingless bees and honey bees) with increasing distance from forest (Klein, Steffan-Dewenter & Tscharntke, 2003). One reason for the higher visitation frequency at the close forest sites maybe most of stingless bees nest in tree cavities, and they are sensitive to disturbance, especially deforestation (Brown & Albrecht, 2001, Eltz, et al 2002).

Bats were more abundant and more highly connected at the far forest sites compared with the near forest sites. This pattern might be the consequence of distance to the cave. We found that the sites that far from forest are closer to the cave which is the roost of nectar bat. From previous study we found that bat visit to durian flowers significantly negatively related to distance to cave and the number of fruits set per inflorescence of durian was not significantly affected by distance to forest; however, affected by the distance to the cave (Sritongchuay et al submitted). The role of bats in pollination has been considered important to many plant species in South East Asia namely, *Durio zibethinus, Musa acuminate, Oroxylum indicum, Parkia speciose, Sonneratia* sp. (Bumrungsri et al. 2009, Gould 1978, Sritongchuay et al. 2010, Stewart et al. 2014)

Proximity to forest on pollination network structure

While a few intensive studies provided information on plant-pollinator communities in tropic regions, our study reports 20 highly comprehensive pollination networks in mixed fruit orchards that near and far from forest edge. The significant differences of connectance, number of links per species, vulnerability, and linkage density, were detected between two study sites. This might be the consequence of significant difference in species richness between study sites because these pollination network structures were strongly affected by species richness, however, differences in some pollination network structures, namely robustness after removing animal species and interaction evenness did not result simply from differences in species richness between both study sites. In close forest networks, network robustness and interaction evenness were higher which could be linked to higher generalism of stingless bees since the network robustness is related to network generalization (Pocock et al 2012)The robustness of pollination networks in ancient heathlands is greater than in restored heathlands sites. Similarly,in host-parasitoid food webs, the interaction evenness has been found to decline with habitat disturbance (Albrecht et al 2007, Tylianakis et al 2007). However, the interaction evenness from agricultural landscape context is lower than in urban areas because of higher generalism of solitary bees, other flies, and Syrphidae in urban areas (Geslin et al 2013). Furthermore, it has been suggested that robustness and evenness could be associated with pollination network stability (Tylianakis et al 2010).

2.4.2 Agricultural and conservation implications

Our finding emphasize how system in mixed fruit orchards based on plant-pollinator interaction may go severe transformation due to the isolated from pollinator sources.Moreover, our finding provide empirical evidence that increasing the distance to pollinator sources reduce the species richness of pollinators, interaction diversity and stability, and in addition may lead to stronger reductions of reproductive success of some economic crops. In context of increasing impact of forest and cave proximity on pollination network, our result can provide possible conservation recommendations concerning plants and animals. Conservation practices aim to preserve the plant-pollinator interaction should promote the maintenance of both generalist flower-visitor groups and specialist plant species such sting less bees, and *Oroxylum indicum*, respectively. However, in many agricultural areas are mostly focused on a single generalist pollinator species such as honey bee, *Apis mellifera*. The importance of honey bees had led to controversy (Aebi et al 2012, Ollerton et al 2012, Garibaldi et al 2013), thus the introduction of honey bee should be done with caution, because they might have negative impact on other generalist pollinator groups. Moreover, to maintain pollinator in orchards, we recommend that agriculture effort to have plant species flowering year round such as *Musa*. This knowledge will promote our understanding of how sustainable conservation policy and practices can be adopted.

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2.6 References

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Table 2. 1 Mean ± SD of pollination network parameters of both near and far study sites.

Quantitative statistic	Mean ± SD		t-value	df	P-value
	Near	Far			
Connectance	0.116 ± 0.022	0.096 ± 0.012	2.859	9	0.019
Web asymmetry	0.542 ± 0.063	0.316 ± 0.107	8.719	9	<0.001
Number of links per species	2.849 ± 0.288	2.103 ± 0.172	7.698	9	<0.001
Compartment	1	1	NA	NA	NA
Nestedness	8.029 ± 2.483	8.404 ± 1.815	-0.442	9	0.669
Robustness lower exterminated	0.715 ± 0.055	0.671 ± 0.041	1.242	9	0.246
Robustness higher exterminated	0.806 ± 0.042	0.768 ± 0.042	4.993	9	0.001
Linkage density	20.106 ± 2.616	10.774 ± 1.669	11.346	9	<0.001
Interaction evenness	0.949 ± 0.020	0.917 ± 0.042	3.045	9	0.014

Table 2.2 Summary of two-way ANOVA to detect significant differences between distance to the forest and bat groups with respect to the species strength of bat in 10 pair of pollination networks.

Source	Sum of Squares	df	F-ratio	P-value
Intercept	15.485	1	105.478	< 0.001
Bat groups	1.725	1	11.753	.002
Distance to forest (near vs far)	1.082	1	7.368	.010
Bat groups * Distance to forest	.069	1	.470	.497
Model	2.876	3	6.530	.001
Error	5.285	36		
Total	23.646	40		

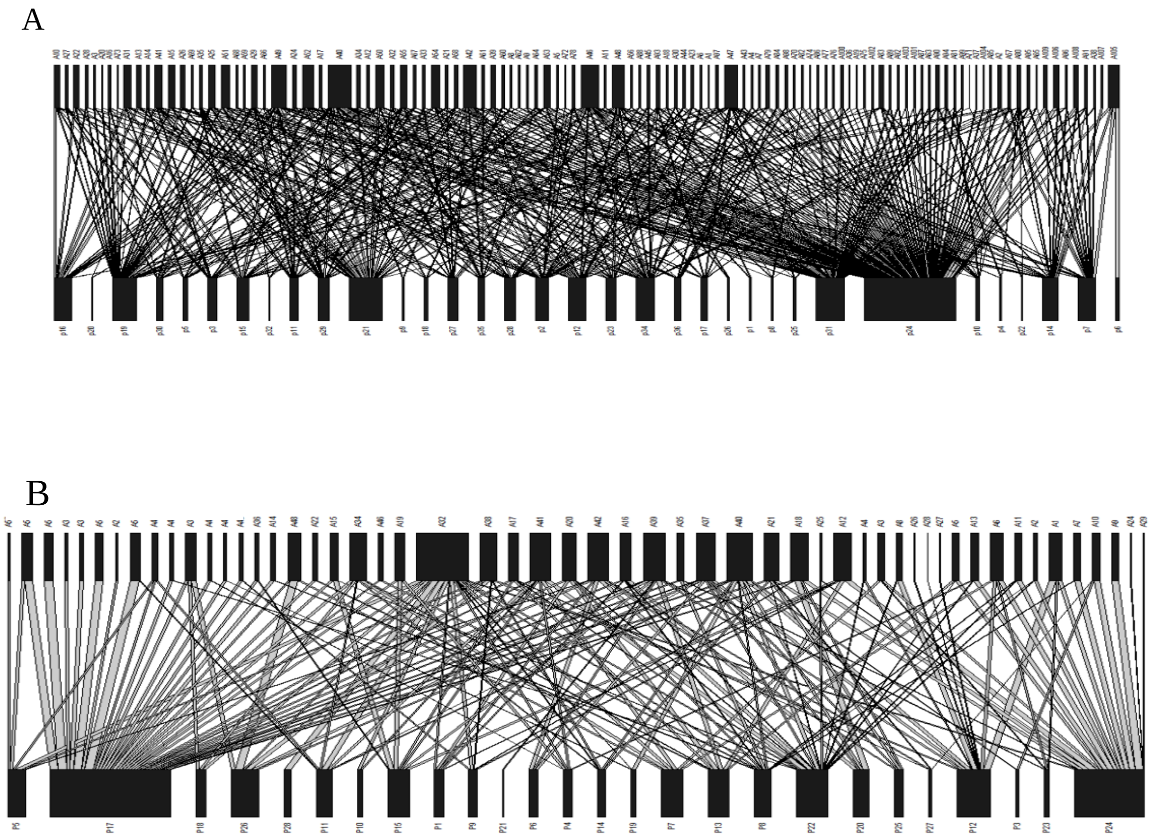

Figure 2.1 Quantitative pollination network (A) at near to forest edge and (B) at far from forest edge. For each web, lower bars represent plant abundance and upper bars represent animal visitor abundance. Linkage width indicates frequency of each organism. Species codes are given in appendix 1.

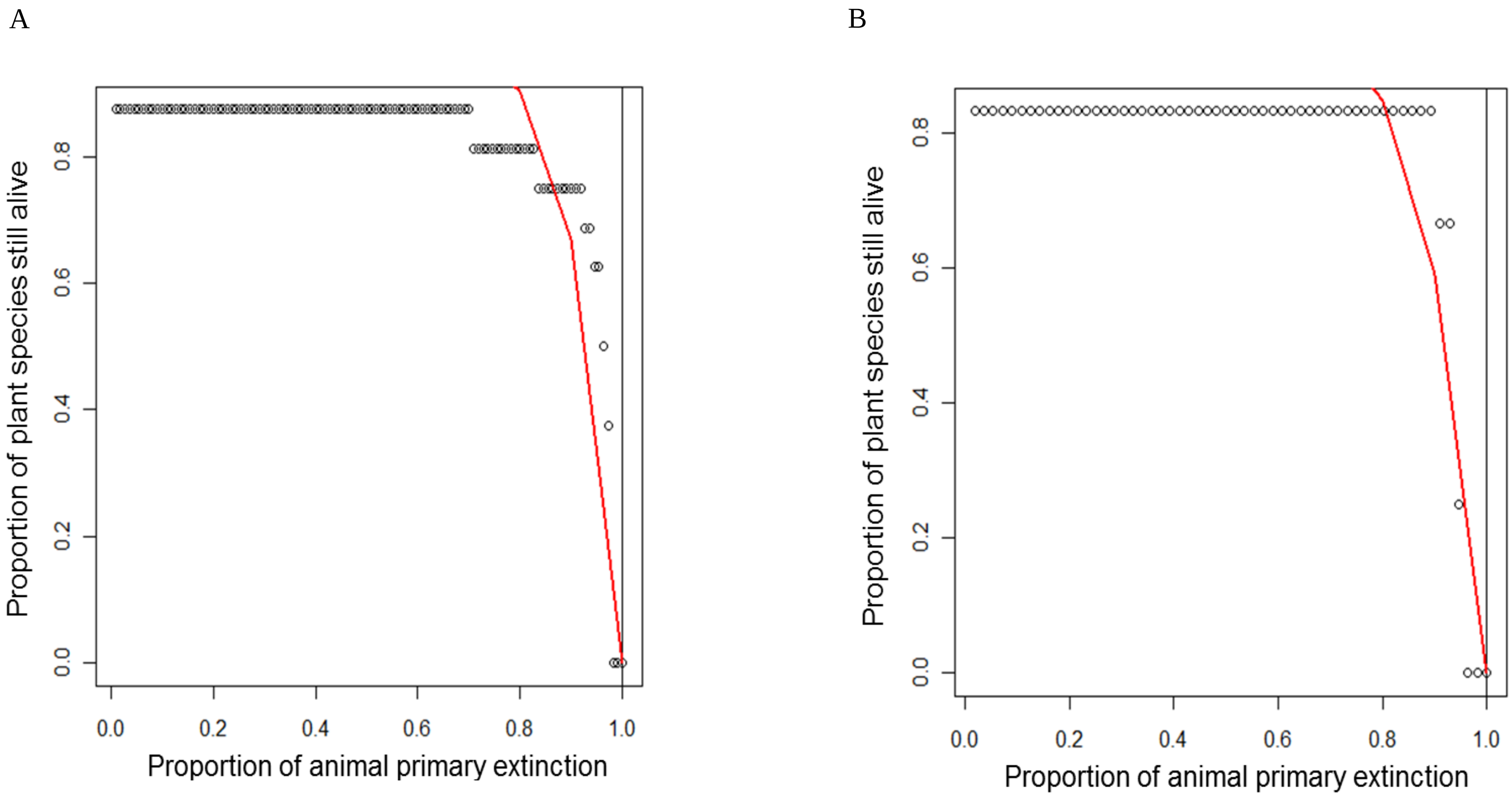

Figure 2.2 Extinction plots following random removal of animal species. A) The decline of plant species and interaction strength (quantitative data) from the network near to forest edge. B) The decline of plant species and interaction strength (quantitative data) from the network far from forest edge.

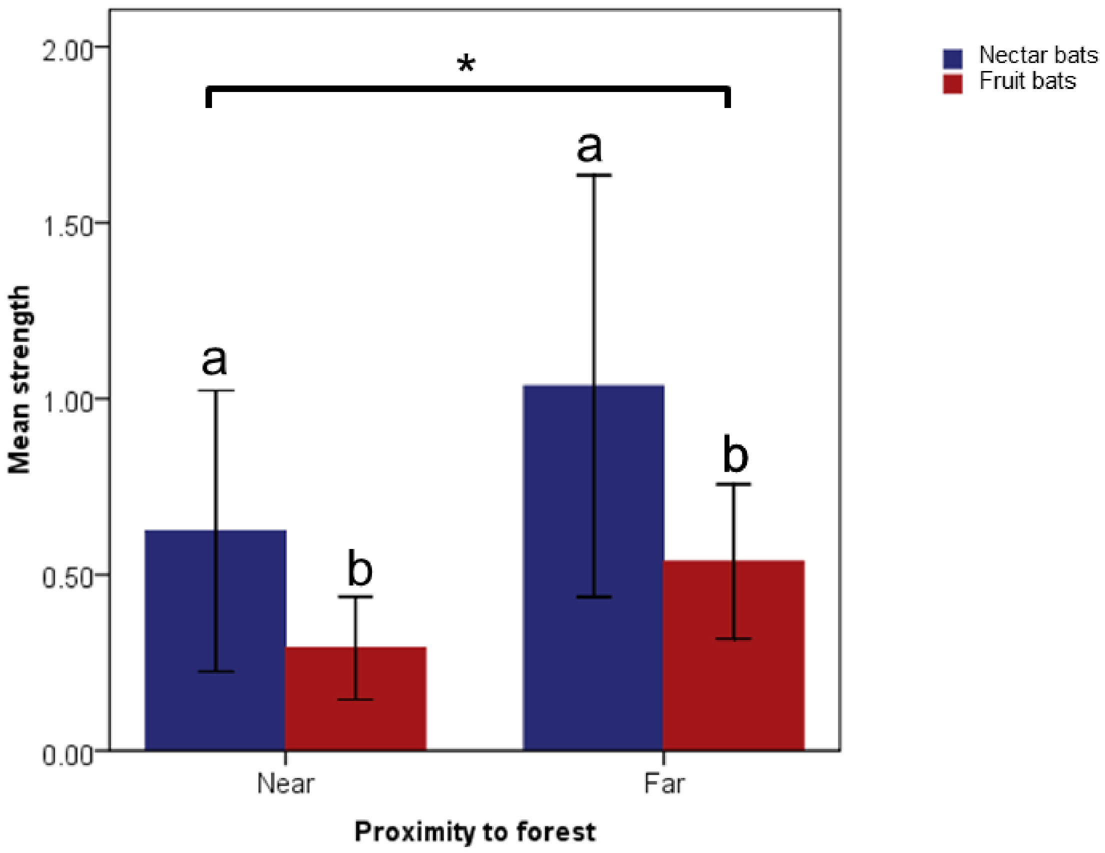

Figure 2.3 Mean of species strength (± SE) of nectarivorous and frugi-nectarivorous bats response to distance to forest edge (near vs far).

CHAPTER 3

Effects of forest and cave proximity on fruit set of tree crops in tropical orchards

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Abstract

Deforestation and forest fragmentation are leading to declines in crop pollinators. To date, most studies have focused on the impact of proximity to forest on the reproductive success and pollination ecology of single crop species in given locations. However, comparing the effect of distance to forest on multiple crop species is important because this distance may have different impacts on different group of pollinators, such as for example, insects versus bats, differentially affecting pollination services. We evaluated flower-visiting animal diversity, visitation frequency and number of fruits set in three species of economic crops: rambutan, durian and mango in 10 pairs of mixed fruit orchards, near (<1 km) and far (>7 km) from forest edge. Mean ± SD of distance from each study orchard to caves is 9.42 ± 7.14_km. The number of fruits set per inflorescence in rambutan sites near forest (22.53 ± 6.33) was significantly higher than far from forest (16.78 ± 4.72). Distance to forest played no role for number of fruits set in durian and mango. The main flower visitors of rambutan were stingless bees. The dominant flower visitor to durian and mango were fruit bats and flies, respectively. The number of fruit set in durian was negatively affected by distance to cave. This study provides empirical evidence that not only forest but also caves can act as a source of flower-visiting agents that provide pollination services to agricultural crops and underscore the importance of tropical rainforest and cave conservation for maintaining such services.

Key words: bat, cave, forest proximity, pollination success, stingless bee, tropical rainforest

3. 1. Introduction

Reproductive success of plant is limited by both pollen and resource. Deforestation which is a major impact in the tropics leading to the smaller and more isolated tropical forest patches show high effects on pollen limitation of plants. Since forests play an important role as pollinator sources for agricultural crops in tropical regions (Ricketts 2004; Klein, Steffan-Deweter & Tscharntke 2003), pollinator declines in farmland may result from forest loss and fragmentation, which lead to larger distances to forest and decreased richness and abundance of crop pollinators. Pollen transfer success such as number of pollen grains deposited on stigmas, number of pollen tubes in style and reproductive success in some crops rely on the number of visitor species and these are known to correlate negatively with distance from natural habitats (Kremen, Williams & Thorp 2002; Kremen *et al.* 2004; Morandin & Winston 2006; Greenleaf & Kremen 2006 a,b; Morandin *et al.* 2007; Winfree *et al.* 2007; Ricketts *et al.* 2008). Most of the studies on natural habitat proximity effects on crop pollination come from temperate regions, however, there have been only few of studies in tropical forest (Heard & Exley 1994; Klein, Steffan-Deweter & Tscharntke

2003 a, b; Blanche & Cunningham 2005; Blanche, Ludwig & Cunningham 2006;). In addition, most of tree species in tropical rain forest are self-incompatible and consequently 94% of plant species in tropical communities are relied on animal pollination (Bawa 1990, Ollerton et al 2011, Corlett, 2014).

Fruit set of some economic crops such as rambutan and mango, common fruit crops for local people in Southeast Asia, depend on insect pollination (Heard, 1999, Dag & Gazit 2000, Carvalheiro et al 2010, Shivaramu et al 2013). However, there are some economic plants whose pollination relies on bats such as durian (*Durio zibethinus*) and both insects and bats such as bitter bean (*Parkia* sp.). For these two plants, the cave-dwelling nectar bat, *Eonycteris spelaea*, is clearly a principal pollinator (Bumrungsri *et al*. 2008; 2009). Moreover, another cave dwelling frugivorous bat, *Rousettus* spp., also facultatively feed on nectar (Nathan et al 2005, Stewart & Dudash, subm) . Thus, proximity to caves might affect durian pollination. Only a few studies have evaluated the consequence of forest fragmentation on the relationship between bats and plant reproductive success (Quesada *et al*. 2003; Quesada *et al*. 2004) and no studies have yet directly evaluated the effect of distance to caves on reproductive success of chiropterophilous plants.

To date, the majority of the studies on the proximity to natural habitat on reproductive success and pollination ecology of crop species were conducted in farms dominated by a single plant species (Morandin & Winston 2005; Greenleaf & Kremen 2006 a,b; Ricketts, Williams & Mayfield 2006; Morandin *et al*. 2007). Uniquely, in tropical region, different species of crop plants are traditionally mixed in fruit orchards (Michon & Mary 1994; Kusumaningtyas, Kobayashi & Takeda 2006).

Diverse flower-visiting species can be maintained by different plant species due to both phenological and nutritional complementarity during different time of the year for example. Additionally, the late flowering plant species would benefit from the presence of an earlier flowering species (Moeller 2004; Blüthgen & Klien, 2011).Therefore, the effect of distance to forest on the pollinator community may be less important than in regions dominated by monocultures. Thus, in this study, we tested the hypothesis that proximity to forest patches affect pollination success of three sympatric species of tropical economic crops that vary in their pollinator requirement. In particular, we asked the following questions: (1) do visitation diversity and frequency of flower-visitor and plant reproductive success change with increasing distance to the forest; (2) for durian, which is bat-pollinated, in addition to proximity to forest, does reproductive success change as distance to the cave increases?

We hypothesized that: the abundance and species richness of pollinators and crop reproductive success will be greater close to the forest. In addition, we predicted that abundance and species richness of frugivorous/nectarivorous bats would be strongly related to cave proximity leading to higher reproductive success of chiropterophilous plant species closer to caves.

3. 2. Materials and method

3. 2.1. Study sites

Mixed fruit orchards are common in southeast asian traditional villages supplying products both for household use and local markets. The common size of orchard patches range from 300 m^2 to 1 km^2. Each orchard consists of multi-storied planted fruit and selected native tree species, as well as herbs and shrubs and resembles a forest in structure and diversity. The best-known example in Thailand is at Lan Saka District, Nakhon Si Thammarat Province, where fruit orchards or 'suan-somrom' have operated for over 100 years (Makarabhirom 1991; Juiprik 1997).The main fruit trees are durian (*Durio zibethinus*), bitter beans (*Parkia speciosa*), mangosteen (*Garcinia mangostana*), domestic jackfruit (*Arthocarpus integer*), longon (*Lansium domesticum*), rambutan (*Nephelium lappaceum*), mango (*Mangifera indica*).

The mixed fruit orchards are distributed among forest patches, (fig. 1). The study took place from September 2012 to June 2013, in 20 mixed fruit orchards situated at varying distances from 10 forest patches in southern Thailand (Nakhon Si Thammarat, Phattalung, Trang, Satun and Songkhla provinces, 6°20'to 8°20'S and 99° 40' to 110°00'E. The actual size of ten patches of tropical rain forest, excluding rubber, and oil palm, ranged in area between 3.6 to 650km^2 and occurred from 230 to 1 090 m elevation. We used 1:133,400 scale photographic imagery from Landsat Thematic Mapper data with a geographic information system (ARC GIS 10.2) to create a map of land use and determine the forest patch size and distances of orchards to the forest edge and to caves. The proportion of forest fractions within 20 km radius in each site was determined. All study species, durian, rambutan, mango, were found in each study site.

Wahala & Huang (2005) reported that mean foraging range of a stingless bee (*Trigona thoracica*) in disturbed area from forest edge is 1.973 km, whereas the mean foraging range of some bats are farther for instance, 1.7 to 6.9 km for *Rousettus* (Bonaccorso *et al*. 2014) and 4.4 km (between 1 and 17.9 km) for *Eonycteris spelaea* based on telemetry data (Acharya *et al.* 2015). Due to the foraging range of various flower visitors, we classified orchards as 'near' if they are< 1 km away from the nearest rain forest patch and as 'far' if they are >7 km away from rain forest. In each forest patch, one pair of near and far orchards was selected and these orchards were at least 10 km from other pairs. We chose the orchards without pesticide application (Farmers, personal communication). Among the pollinators, the nectar bat, *Eonycteris spelaea*, has the longest average foraging range of 4.4 km from its roosting site. We therefore deemed sites spaced at 10 km as independent. Distance from each study orchard to nearest caves where bats may roost ranged from 0.7 to 29 km. The data of bat roosting caves (Bumrungsri 1997; http://www.thailandcaves.shepton.org.uk) were used.

3. 2.2. Study species

Nephelium lappaceum (rambutan, Sapindaceae) The major flowering season is from March – May, with occasional flowering from August to October, depending on local weather conditions (Whitehead 1959). The flowers are white and either male or hermaphrodite in different inflorescences. Rambutan is dioecious but the male plant is rare. On the male panicle, the number of flowers per inflorescence is approximately 1 000 – 5 000 buds. On the hermaphrodite flower, each panicle may contain around 200-800 flowers. Anthesis starts at about 07h00 and co-occurs with stigma receptivity. Stigma remains receptive for a day. Nectar secretion starts at anthesis in both types of flower. Rambutan is self-incompatible plant so that the reproductive success of this plant definitely depends on pollinator such as *Trigona* and *Apis* *ceranna* (Lim 1984; Van Welzen, Lamb & Wong 1988; Heard 1999; Shivaramu, Sakthivel & Reddy 2013).

Durio zibethinus (durian, Bombacaceae) is widely distributed and cultivated throughout South East Asia. In southern Thailand, flowering starts from March to May and last for about 2-3 weeks. Flowers are hermaphrodite. Each inflorescence is composed of 3-100 greenish-white flowers. Flower open late in the afternoon (16h00) when the petal lobes started to separate (Bumrungsri *et al*. 2009). Nectar secretion starts in the late afternoon after flower opened. Anthesis occurs at 19h30-20h00 and the stigma is already receptive when anthers release pollen. Very low pollination success in facilitated autogamy compared to crossed pollination (1.2% vs 12.2 % fruit set after 2 months) suggests that most durian trees are highly self incompatible. Pollen limitation have found in previous studies (Bumrungsri *et al*. 2009) and the main visitors are nectarivorous bat (*Eonycteris spelaea*) and giant honey bee (*Apis dorsata*)(Bumrungsri *et al*. 2009; Stewart, Makowsky & Dudash 2014).

Mangifera indica(mango, Anacardiaceae) Most of observed mango plants were “Bao”variety, which show two flowering period peaks in February and September. The flowering period lasts for ten days after the first bud opens. The inflorescence of mango is composed of hermaphrodite and male flowers. The pistil is abortive in male flowers. The percentage of hermaphrodite flowers varies from 1.25 – 35.6. Mango flowers open during the night and early morning (by 08h00). Dehiscence of anthers takes place at 11.30 a.m. and it continues up to 3.45 p.m. Flowers secrete nectar and stigma becomes receptive when the flower opens (Mukherjee 1953). Fruit set following self-pollination was fewer (0.0 to 1.68%) compared with that after cross-pollination (6.4 to 23.4%) and overall fruit set rate is very low that only 0.1 percent of hermaphodite flowers set fruits to mature (Sharma & Singh, 1970, Carvalheiro et al, 2010). The main flower-visitors are insects from the orders Diptera, Hymenoptera, Lepidoptera and Coleoptera (Sharma & Singh 1970, Dag et al 2000, Carvalheiro et al, 2010).

3. 2.3. Sampling of flower visitors

We selected ten trees per species per site for both flower visitation studies and the evaluation of reproductive success (see below). We selected the inflorescences with similar size from the middle part of those trees that had many flowers. We observed the insect visits for approximately 5 mins per inflorescence and one 15 mins session per tree. When insects were encountered the flowers, we stopped the timer to identify and count the number of insects. We recorded both insect visit frequency (number of visiting times) and insect richness and the number of flowers observed. Surveys were conducted from 08h00 to 11h00 and from 15h00 to 19h00 recording the frequency of insect visits. The observations were conducted in calm weather (i.e. sunny and without rain, temperature ranging from 31 º C to 38 º C). Following observations, we collected samples of flower visitors with sweep nets. Some common insects that could not be identified to species were grouped to morpho-types (Memmott & Godfray 1993). Both the near and far study sites for each forest patch were sampled on the same day.

The activity of nocturnal visitors was recorded by camera traps (Moultrie game spy d55-IRXT infrared flash camera) set at 5 to 10 m from each inflorescence used for the reproductive success experiment for each crop species. Bats also were surveyed by mist-netting in each study site to confirm bat species from camera traps. Mist nets were set as close as possible to the flowers of durian. Three 2.6 x 6 m^2 mist nets were set per site, they were opened from 19h00 to 02h00, deployed for 2 nights in each orchard. Visiting bats were identified to species following *The mammals of Thailand and South-East Asia* (Francis 2008) mainly from its external morphology and size. Based on camera traps, the number of visits for each bat species per night was determined for each inflorescence.

3. 2.4. Reproductive success

Three inflorescences were marked for each of the 10 trees using tie wraps and left exposed to open pollination. We selected those inflorescences that had similar number of flower buds. Number of fruits per inflorescence were counted for each individual tree, approximately two weeks after the tree finished flowering, avoiding resource limited effect. However, for durian we examined the number of fruits set at 4 week after the tree finished flowering because this species shows late-acting self-incompatibility (Bumrungsri *et al.* 2009; Honsho *et al.* 2007). Reproductive success was indicated as the number of fruits set.

3. 2.5. Statistical analyses

For each of the three crop species, the response variable, number of fruits set in each inflorescence, was examined using a generalized linear mixed model (GLMM), comprising a logit link function. Distance to forest, forest patch size, orchard patch size, distance to nearest cave, proportion of forest surround study sites, visitor richness and visitor frequency were considered to be explanatory variables. Individual tree, study site and forest patch were treated as random factors. To find the best scale for forest proportion, we conducted regression between proportion of forest surround each study site at different radius scales (2, 4, 8 km) on the number of fruit set of 3 crop species. The number of parameters minimized the goodness of fit given by the Akaike's information criterion (AIC, Burnham & Anderson 2001). To determine the best predictive model, the GLMM having the lowest AIC were selected.

For crops in which distance to forest was found to be a significant variable explaining fruit set, Generalized Linear Models (GLM) were conducted to examine the relationship between the stingless bee visit frequency, number of visiting insect species and distance to forest. All statistical analyses were performed using R, version 2.13.0 (http://www.R-project.org).

3. 3. Results

3. 3.1. Rambutan

The number of fruits set per inflorescence in sites near forest (Mean± SD = 22.53±6.33) was significantly higher than far from forest (Mean± SD = 16.78±4.72). There was also a positive effect of insect visit frequency on number of fruits set, with a linear increase (Fig. 3.2, Table 3.1). However, forest patch size and insect richness had no effect on fruit set. There was a positive significant interaction between the proximity to forest and insect richness (Table 1).The most abundant flower visitors were stingless bees (70.87%) and honey bees (*Apis cerana*, 10.68%), Diptera (9.34%), followed by other insects (9.11%)(n= 4,756). Stingless bees were significantly more frequent at rambutan flowers near forest (Mean ± SD = 40.76± 23.55 times) than far from forest (Mean ± SD = 25.41 ± 17.44 times, $F_{1, 598} = 897.14$, $P < 0.001$). We found the proportion of forest within 2 km radious from orchard show significant effect on the number of fruit set in rambutan (GLM, *F* = 23.25, *df* = 598, *P* < 0.001), whereas there was not significant effect in durian and mango.

3. 3.2. Durian

The number of fruits set per inflorescence of durian was not significantly affected by distance to forest; however, the effect of distance to the cave on the number of fruits set was negatively significant. Bat visit significantly negatively related to distance to cave. Bat visit frequency was higher when the distance to cave decreased (Table 3.2, Fig. 3.3). The nocturnal flower visitors of durian were fruit bats and giant honey bees (*Apis dorsata*), while diurnal visitors were stingless bees, giant honey bees (*Apis dorsata*) and honey bees (*Apis cerana*). The bat visit frequency from camera trap declined sharply with the distance to cave (Fig.3). The data from camera traps showed that main bat species were *Eonycteris spelaea* (63.89%), *Cynopterus* spp. (19.62%), other species (16.48%) (n =3,039 times). From 480 net hour effort, 271 individuals of six fruit bat species (*E. spelaea* (94), *Macroglossus sobinus* (52), *Rousettus amplexicaudata* (51), *R. leschenaulti* (30), *Cynopterushorsfieldi* (20) and *C. brachyotis* (25)) were netted.

3. 3.3. Mango

We found no significant difference of fruit set of mangoes per inflorescence between sites near forest (Mean± SD = 8.37± 2.98) and far from forest (Mean± SD = 8.11±2.90) or with forest patch size (Table 3.3). None of the visitor variables affected the number of fruits set per inflorescence. The main flower visitors of mango were flies (65.24%), stingless bees (9.45%), honey bees (12.19%), beetles (5.24%) and other insects (7.86%). For visiting flies, they are mainly from family Muscidae (house fly), Calliphoridae (blow fly), Syrphidae (hover fly). Fly visit frequency alone also did not significantly affect the number of fruits set (GLM, $F = 0.0003$, $df = 598$, $P = 0.986$)

3. 4. Discussion

3. 4.1. Proximity to forest on fruit set

Our results show that the effect of distance to forest on the number of fruits set in rambutan, durian and mango differed between plant species depending on the pollinating guild. Pollination success in rambutan was enhanced substantially by proximity to forest, while distance to forest played less role for numbers of fruit set in durian and mango. This pattern was likely a consequence of the dependency of the main flower visitors of each plant species on forest. Pollination success in rambutan was positively related to insect visit frequency. Since stingless bees made up more than 50% of the visitors to rambutan, these results suggest that stingless bees are potentially the major pollinating insects for this species. For rambutan, we established for the first time that pollination success, represented by the number of fruits set per inflorescence, relied on insect visit frequency. A previous study support that wild insect pollinators are more effective than honey bees, for instance increasing in the wild insect visitation cause twice number of fruit set after increase in honey be visitation (Garibaldi et al 2013). Similar strong effects of proximity to tropical forest for crop pollination success have been found in other plant species, including coffee, which the number of fruit set relate to the richness of flower-visiting bee species (Klein, Steffan-Dewenter & Tscharntke 2003). Blanche, Ludwig & Cunningham

(2006) found that pollination success in both macadamia and longan were negatively related to the distance to tropical rainforest and major pollinating insects of longan are stingless bees. Similarly, Ricketts (2004) found that bee diversity, visitation rate, pollen deposition rate and fruit set were all affected by the proximity to forest. Moreover, from GLM analysis, the proportion of forest within 2 km around each site affected on the number of fruit set of rambutan, similar to the study of Kremen *et al*. (2004) and Winfree *et al.* (2007) that shown the proportion of natural habitats strongly affected on the native bee communities. However, from GLMM analysis the proportion of forest around each site was not effect the number of fruit set, this might be a consequence of autocorrelation between proportion of forest around study sites and distance to forest.

The distance to forest did not affect number of fruit set in durian because insects have less effect on pollination success of this crop. Fruit bats, especially *E. spelaea* are the important pollinator of durian flower, even though, the giant honey bee (*Apis dorsata*) was the most frequent nocturnal visitor to the flowers. Based on experiments , one month after pollination, no fruit set from insect pollination alone, whereas about 10 % from open pollination set fruit (Bumrungsri et al 2009). Our results show a strong negative relationship between distance to cave and number of fruits set in durian. There are only few studies about bat pollinators in relation to forest fragmentation. Previous authors have found pollination success of chiropterophilous plants was affected by forest fragmentation (Stoner *et al.* 2002; Quesada *et al.* 2003; Quesada *et al.* 2004). This is the first study, that document that bat visit frequency decrease accordingly with distance from cave and lead to decreasing in pollination success of chiropterophilous species.

Distance to forest did not contribute significantly to fruit set of mango. A likely explanation for this pattern is that mango in the study area is probably pollinated by flies, the major visitors which their abundance may not be sensitive to proximity to forest as found in hover flies (Steffan-Dewenter & Tscharnke 1999). A study on pollinators of mango in Israel found blow flies are as effective pollinator as honey bees (Dag & Gazit 2000). However, in South Africa where the most abundant visitors were ants and honey bees, increasing distance from natural habitat lead to strong declines in production of mango (Carvalheiro *et al.* 2010). In contrast to Diptera, abundance of insects from order Hymenoptera decrease with increasing distance to forest (Steffan-Dewenter & Tscharnke 1999).

3. 4.2. Proximity from forest on richness and abundance of flower visitors

The higher visitation of stingless bees to rambutan flowers near forest suggests that rainforest is a source of these bees. Similarly, sampling bees in Indonesian agroforestry systems detected a decrease in richness and abundance of social bees (Meliponini and Apini e.g. stingless bees and honey bees) with increasing distance from forest (Klein, Steffan-Dewenter & Tscharntke, 2003). Since most of stingless bees nest in tree cavities, they are sensitive to disturbance, especially deforestation (Brown & Albrecht, 2001, Eltz, et al 2002). The effect of distance to forest on the abundance of flower visitors may be greater for smaller wild bee species because body size acts as a limiting factor in maximum flight distance (Steffan-Dewenter &Tscharntke 1999; Gathmann &Tscharntke 2002; Araújo *et al*. 2003; Greenleaf *et al*. 2007). We did not detect such an effect of species richness for any of the crops studied, however, possibly this could be due to the low taxonomic resolution since we were not able to identify every insect to species level.

The higher visitation rate of bats to durian flowers near the cave emphasize the role of caves as sources of pollinators to surrounding durian. The nectar cave dwelling bat, *E. spelaea* were the most abundant bat species (approximately, 60% of bats observed at flowers) and has previously been shown to be an important pollinator of durian (Bumrungsri exclusion study). Further durian constitutes about 42% of the diet of captured *E. spelaea* in March and April, during flowering season (Bumrungsri *et al.* 2013), showing that *E. spelaea* is a faithful visitor to durian. In addition, from the mist net result, about 30% of captured bats were *Rousettus* which is also cave roosting bat. Based on these data, we suggest that this bat group is probably also important for pollination of durian orchards near to roosting caves, although these were not observed at durian flowers by camera trapping.

3. 4.3. Agricultural and conservation implications

It is clear that rainforest acts as a reservoir for stingless bees that enhance rambutan pollination. Moreover, forests may harbour diverse pollinators for many other crops. Preservation of forest will ultimately protect nesting and foraging habitat of many key pollinators of our crops and thus maintain the richness and abundance of these vital pollinators (Ricketts 2004). However, most intensive agricultural farms have not incorporated nesting and foraging site provision in their normal farming practise (Kremen, Williams & Thorp 2002; Tscharntke *et al.* 2005). For bee, our most important crop pollinator, nest provision is an alternative way for maintain its population in area far from forest. In last ten years, the keeping of stingless bees has grown rapidly in Australia and 24% of bee keepers are using their bees for crop pollination such as macadamia, lychee, watermelon, avocado and mango (Heard & Dollin 2000; Halcroft *et al*. 2013). In Thailand, the stingless bee domestication have been applied in rambutan orchards in Eastern part, however, the stingless bee-keeping in other regions of Thailand and tropical countries is not yet widely applied for crop pollination. Thus we recommend fruit growers to keep bee hives in their farms and to preserve forest remnants. In addition, more environmental friendly agricultural practise such as agroforestry, should be implemented in the large scale to facilitate greater nesting and floral resources for these pollinators throughout the entire year.

In addition to insect pollinators, caves and populations of the bat, *E. spelaea* and *Rousettus* should also be protected. A recent investigation estimated that the annual economic contribution of fruit bats in pollinating bitter bean and durian in southern Thailand was over 137 million US $ in 2008 (Petchmunee, 2008). Due to its self-incompatibility and reliance on fruit bats for pollination, the future survival of durian appears to depend on the survival of these bats. Serious declines in populations of some fruit bats such as *E.spelaea* from hunting in some areas including Thailand have been reported (Mickleburgh,Hutson & Racey 1992; S.Bumrungsri, pers. obs.). As a consequence, the likelihood of pollination failure in durian may increase. *E. spelaea* (Bumrungsri 1997; Start 1974), is also known as the major pollinator of other economically and ecologically important plants including indian trumpet flower (*Oroxylum indicum*), petai (*Parkia speciosa*), *P. timoriana, Sonneratia* spp. and *Duabanga grandiflora* (Start & Marshall 1976; Hopkins 1994; Bumrungsri *et al*. 2008; 2009; 2013; Srithongchuay *et al*. 2008). Mixed planting of these species can maintain the visit of fruit bats to fruit orchards. A recent study indicated that *E.*

spelaea has a strong fidelity to its foraging area (Acharya *et al*. 2015). Thus, protecting bat populations and their roosts and mixed crop planting is necessary for maintaining both crop yields and ecological complexity. However we lack of support data on pollination experiment of these three plants in other countries so we have to assume that the similar pattern might be found in other areas too.

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Table 3.1. Results of generalized linear mixed models for the number of fruits set of rambutan, Fixed effects are distance to the forest edge, forest patch size, insect richness, and insect abundance, AIC = 946.5

Explanatory fixed variable	Estimate	SE	z-value	p-value
Intercept	2.815	0.020	142.22	<0.001***
Distance to forest edge (Near)	0.268	0.024	11.29	<0.001***
Insect richness	-0.003	0.023	-0.15	0.880
Insect visit frequency	0.049	0.023	2.18	0.030 *
Distance to forest edge * Insect richness	0.076	0.027	2.88	0.004 **
Distance to forest edge* Insect visit frequency	0.048	0.025	-1.89	0.059
Insect visit frequency* Insect richness	0.036	0.022	1.66	0.096
Distance to forest edge* Insect visit frequency* Insect richness	-0.035	0.025	-1.43	0.152

Table 3.2. Results of generalized linear mixed models for the number of fruits set of durian, fixed effects are distance to the forest edge, distance to cave, bat visit frequency, proportion of forest within 20 km and insect visit frequency, AIC = 627.5

Explanatory fixed variable	Estimate	SE	z-value	p-value
Intercept	1.919	0.082	23.26	<0.001***
Distance to forest edge (Near)	0.010	0.049	0.212	0.832
Distance to cave	-0.119	0.053	-2.245	0.025*
Proportion of forest area	-0.215	0.226	-0.951	0.342
Insect visit frequency	-0.008	0.034	-0.246	0.805
Bat visit frequency	0.199	0.042	4.658	<0.001***

Table 3.3. Results of generalized linear mixed models for the number of fruits set of mango, fixed variables are distance to the forest edge, forest patch size, insect richness, and insect visit frequency, AIC = 621.2

Explanatory fixed variable	Estimate	SE	z-value	p-value
Intercept	2.08007	0.02476	84.02	<0.001
Distance to forest edge (Near)	0.05701	0.03995	1.43	0.154
Forest patch size	0.03334	0.04737	0.70	0.482
Insect richness	-0.02327	0.03110	-0.75	0.454
Insect visit frequency	-0.02012	0.04644	-0.43	0.665

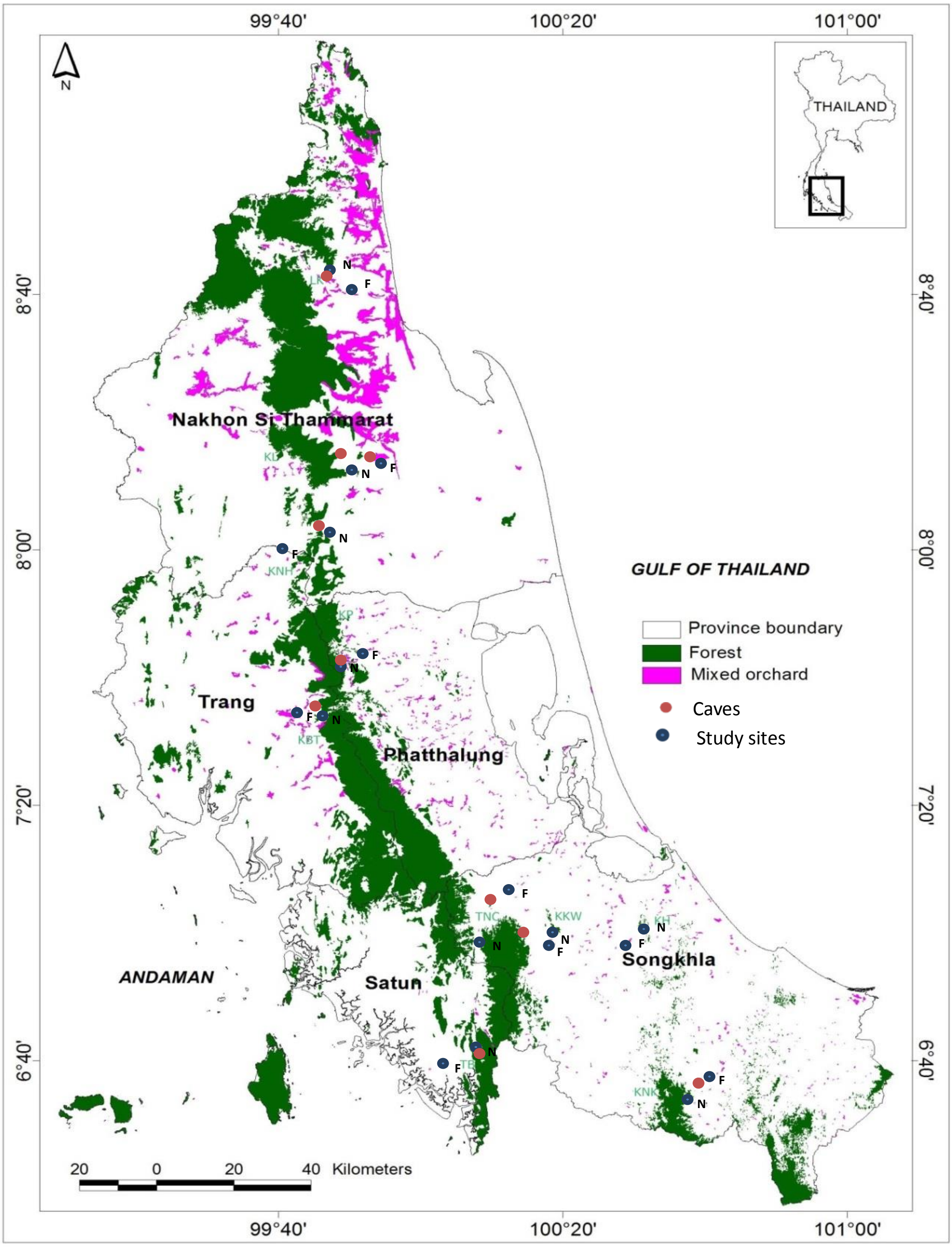

Figure 3.1 Map of study site, visitors and fruit set were sample from 20 orchards from varying distances from 10 forest patches.

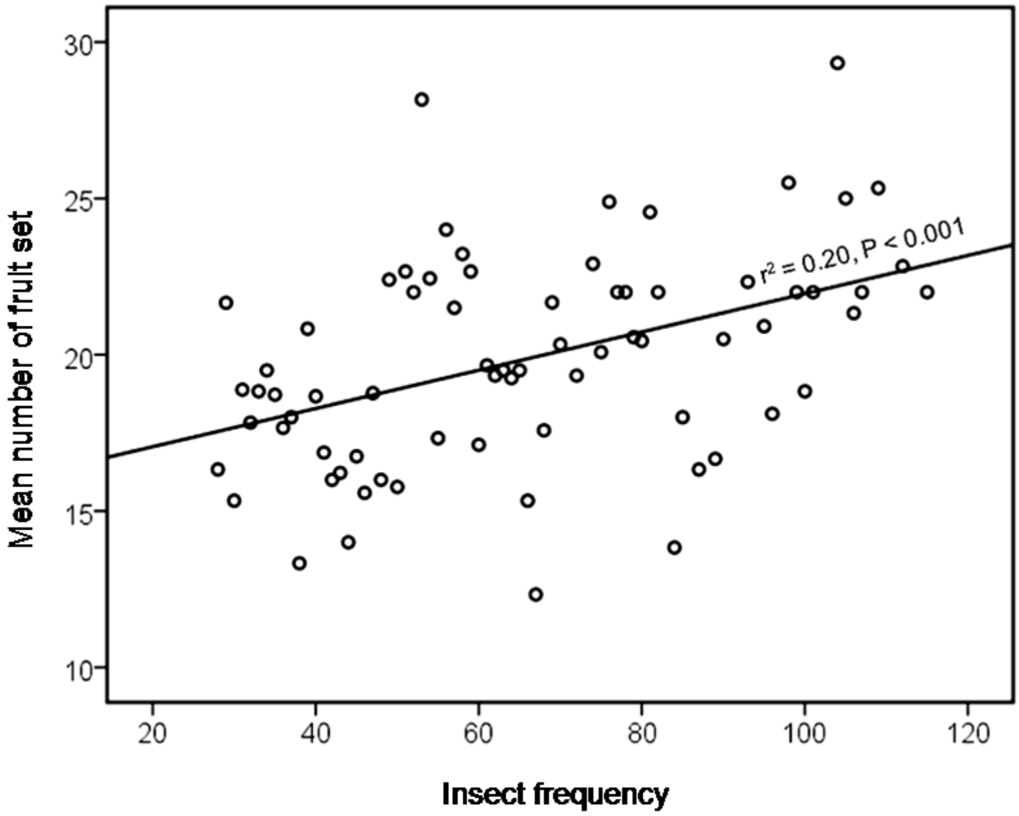

Figure 3.2 A linear regression plot between number of fruit set and insect visit frequency for Rambutan. The data points were based on the mean number of fruit set from one inflorescence.

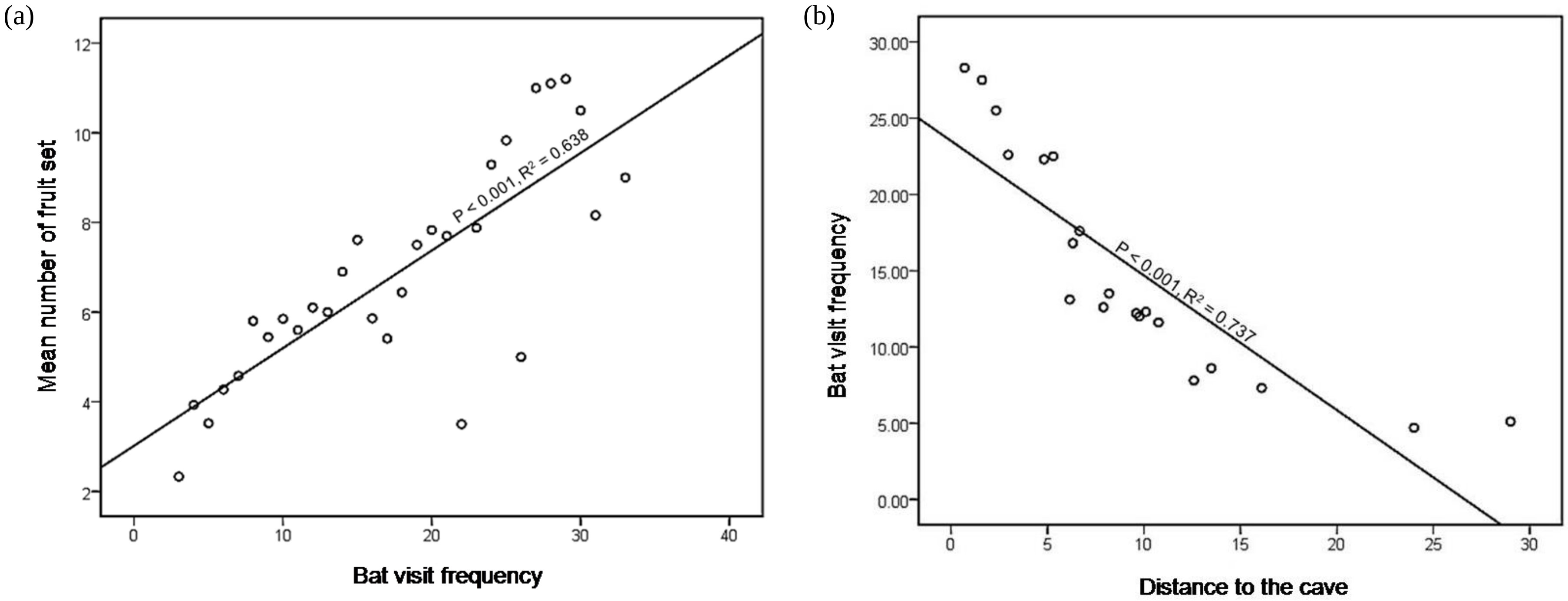

Figure 3.3 a) A linear regression plot between number of fruit set and bat visit frequency in durian. b) A linear regression plot between bat visit frequency in durian and distance to cave. The data points were based on the number of fruit set from one inflorescence.

CHAPTER 4

DISCUSSION AND CONCLUSION

One of the greatest challenges of us is how to reconcile the needs of humankind with the healthy natural systems. This thesis investigates the effects of forest and cave proximity on the structure of pollination network, pollination ecology and reproductive success of some crops in mixed fruit orchards. In this final chapter I will summarize the main findings of each previous data chapters and put them into the general context of network ecology, and application for conservation, and agriculture. I end by highlighting potential paths for future research in this field.

Chapter 2 we used quantitative pollination network approach to investigate two main objectives; 1) to compare pollination network structure from mixed fruit orchards at near and far from forest edge the pollination network structure in mixed fruit orchards at near and far from the forest and 2) to determine the effect of proximity to forest and the bat groups on the species strength of bat in pollination network. The average number of visitor-flower interactions was higher at sites near to forest edge, as well ass, other network indices, including connectance, number of links per species, robustness after removing animal species, linkage density, and evenness but nestedness were not significant different between both sites. The species strength of bat in pollination network was not effect by forest proximity but species strength was different between bat groups. We conclude that the proximity to forest edge as well as to the cave affect to pollination network structure that has implications that the pollination network from orchards at near to pollinator sources have higher complexity, and stability and the resilience for perturbations.

Chapter 3 we studied the pollination ecology of three economic crops, rambutan, durian, and mango in mixed fruit orchards in different distance from forest edge and caves. The number of fruits set in rambutan sites near forest was significantly higher than far from forest, and this was correspond with the abundance of pollinator whereas distance to forest played no role for number of fruits set in durian and mango because the pollinator of these three plants are different. The main flower visitors of rambutan were stingless bees. The dominant flower visitor to durian and mango were fruit bats and flies, respectively. The number of fruit set in durian was negatively affected by distance to cave. Our findings provide the first evidence of the significance of distance to the cave on the pollination ecology and reproductive success of bat pollinated plant. Thus not only forest but also caves can act as a source of flower-visiting agents that provide pollination services to agricultural crops.

These results add to the mounting evidence that the lack of landscape connectivity and the subsequent isolation of habitat patches can interfere with pollination. Similarly, many empirical studies found that probability of extinction of a local population is positively related to its isolation (Ouborg, 1993, Rodriguez & Delibes, 2003). There are broader set of conservation options to protect such extinctions would be 1) to increase the carrying capacity of local populations, by increasing either the habitat area (Hodgson et al., 2011) or the habitat quality. However, the re-allocation of large areas of forest is practically difficult option in human-dominated landscapes. Improving habitat quality is more feasible. 2) To increase landscape connectivity. Thus we suggest that farmers preserve big tree and effort to have plant species flowering year round such as *Musa* in orchard to provide material for nest and food for pollinators as well as preserve the remnant forest sand limestone caves even the small area to increase the landscape connectivity. We also suggest the farmers to practice Diversified Farming System (DFS, Kremen et al 2012), which promote functional biodiversity across ecological, spatial, and temporal scale. For example in plot scale, diversified farming system may include mixed varieties of crop. In the field scale, farmers might apply living fences and hedgerows, and at the landscape scale the farmers might incorporate natural or seminatural plants and animals communities into their farming system.

Future studies

Our approach still as several key limitations that will need to be address in future studies. First, the lack of identification to the species level for insects. Particularly, in some insect groups such as stingless bees, we can identify as the morphotypes thus study pollination network at species level along the distance gradient to pollinator sources should greatly improve our knowledge. Second, we estimate plant reproductive success by measuring number of fruit set in two weeks after flower open. However, in future study will need to estimate the reproductive success of plant by counting the mature fruits to gain the economic value of ecosystem services. Third, the distinguish between flower visitor and effective pollinators is still untested, so verifying whether visitors are pollinator in pollination network need to be highlighted. There is a need to gain knowledge of how organism and their interaction network respond to various threats such as climate change, biological invasions, and intensive agriculture such as pesticide application. We should disseminate about ecological and economical significant of pollination services to farmers and raise awareness about forest, caves and bats, since that is more likely to influence local protection of forest and caves.

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Appendix

Table 4.1 Interaction of plant and pollinator from one study site near to forest

Animal group	ID	Animal species	Plant species	Plant ID	Number of visits
Beatles	A1	*Chlorophorus annularis* (Cerambycidae)	*Musa sapientum* L.(Musaceae)	P24	22
			Mangifera indica L. (Anacardiaceae)	P1	10
			Citrus	P30	3
	A2	*Aulacophora sp.* (Chrysomelidae)	*Musa sapientum* L.(Musaceae)	P24	30
			Sandoricum koetjape Merr. (Meliaceae)	P19	13
			Theobroma cacao L.(Malvaceae)	P16	5
			Dipterocapus sp.(Dipterocarpaceae)	P12	9
			Durio zibethinus L.(Bombacaceae)	P7	36
			Capsicum frutescens L.(Solanaceae)	P34	13
	A3	*Luperomorpha* sp. (Chrysomelidae)	*Sandoricum koetjape* Merr. (Meliaceae)	P19	21
			Mangifera indica L. (Anacardiaceae)	P1	5
			Zalacca edulis Reinw.(Arecaceae)	P3	9

	A4	*Episomus* sp. (Chrysomelidae)	*Musa sapientum* L.(Musaceae)	P24	22
			Capsicum frutescens L.(Solanaceae)	P34	15
	A5	Alaus sp.(Elateridae)	*Musa sapientum* L.(Musaceae)	P24	21
			Mangifera indica L. (Anacardiaceae)	P1	16
			Garcinia mangostana L.(Clusiaceae)	P11	7
	A6	*Lycostomus* sp.1 (Lycidae)	*Musa sapientum* L.(Musaceae)	P24	23
			Capsicum frutescens L.(Solanaceae)	P34	21
	A7	*Lycostomus* sp.4 (Lycidae)	*Musa sapientum* L.(Musaceae)	P24	20
			Dipterocapus sp.(Dipterocarpaceae)	P12	10
	A8	unidentified sp. (Cantharidae)	*Musa sapientum* L.(Musaceae)	P24	20
			Azadirachta indica A. Juss.(Meliaceae)	P21	23
	A9	unidentified sp.2 (Cantharidae)	*Musa sapientum* L.(Musaceae)	P24	19
			Capsicum frutescens L.(Solanaceae)	P34	22
			Areca catechu L. (Arecaceae)	P5	9
	A10	*Gametis histrio* Olivier (Scarabaeidae)	*Zalacca edulis* Reinw.(Arecaceae)	P3	13
			Sandoricum koetjape Merr. (Meliaceae)	P19	25

			Theobroma cacao L.(Malvaceae)	P16	35
			Azadirachta indica A. Juss. (Meliaceae)	P21	2
			Artocarpus heterophyllus Lam. (Moraceae)	P23	11
			Morinda citrifolia (Rubiaceae)	P27	15
			Citrus	P30	17
	A11	*Glycyphana nicobarica* Janson (Scarabaeidae)	*Garcinia mangostana* L.(Clusiaceae)	P11	8
			Fragraea fragrans Roxd. (Gentianaceae)	P15	6
			Musa sapientum L.(Musaceae)	P24	23
	A12	*Glycyphana* quadricolor (Scarabaeidae)	*Sandoricum koetjape* Merr. (Meliaceae)	P19	16
			Lansium domesticum L.(Meliaceae)	P20	12
			Musa sapientum L.(Musaceae)	P24	20
			Clausena cambodiana Guill. (Rutaceae)	P28	20
			Capsicum frutescens L.(Solanaceae)	P34	17
	A13	*Ixorida mouhotii* Wallace (Scarabaeidae)	*Theobroma cacao L.*(Malvaceae)	P16	46
			Azadirachta indica A. Juss. (Meliaceae)	P21	23

			Musa sapientum L.(Musaceae)	P24	19
			Morinda citrifolia (Rubiaceae)	P27	12
	A14	Unidentified (Staphylinidae)	*Zalacca edulis* Reinw.(Arecaceae)	P3	15
			Sandoricum koetjape Merr. (Meliaceae)	P19	9
			Citrus aurantifolia Swingle. (Rutaceae)	P29	8
			Capsicum frutescens L.(Solanaceae)	P34	15
Fly	A15	*Proctacantella* sp. (Asilidae)	*Garcinia mangostana* L.(Clusiaceae)	P11	21
			Parkia speciosa Hassk. (Fabaceae)	P14	7
			Theobroma cacao L.(Malvaceae)	P16	53
			Lansium domesticum L.(Meliaceae)	P20	13
			Azadirachta indica A. Juss. (Meliaceae)	P21	34
	A16	Systropus sp.3 (Asilidae)	*Fragraea fragrans* Roxd. (Gentianaceae)	P15	11
			Sandoricum koetjape Merr. (Meliaceae)	P19	18
			Morinda citrifolia (Rubiaceae)	P27	21
			Citrus (Rutaceae)	P30	15

	A17	*Chrysomyia megacephala* Fabricius (Calliphoridae)	*Mangifera indica* L. (Anacardiaceae)	P1	8
			Theobroma cacao L.(Malvaceae)	P16	21
			Musa sapientum L.(Musaceae)	P24	21
			Etlingera elatior (Jack.) R.M. Smith. (Zingiberaceae)	P35	9
	A18	Chrysomyia sp.1 (Calliphoridae)	*Mangifera foetida* Lour. (Anacardiaceae)	P2	16
			Mangifera indica L. (Anacardiaceae)	P1	9
			Sandoricum koetjape Merr. (Meliaceae)	P19	7
			Musa sapientum L.(Musaceae)	P24	23
	A19	Hypopygropsis sp. (Calliphoridae)	*Mangifera indica* L. (Anacardiaceae)	P1	6
			Musa sapientum L.(Musaceae)	P24	24
	A20	unidentified sp. (Calliphoridae)	*Mangifera indica* L. (Anacardiaceae)	P1	6
			Sandoricum koetjape Merr. (Meliaceae)	P19	18
	A21	unidentified sp. (Dolichopodidae)	*Mangifera indica* L. (Anacardiaceae)	P1	7
			Zalacca edulis Reinw. (Arecaceae)	P3	19

			Sandoricum koetjape Merr. (Meliaceae)	P19	9
			Musa sapientum L.(Musaceae)	P24	24
			Morinda citrifolia (Rubiaceae)	P27	10
	A22	Drosophila sp. (Drosophilidae)	*Dipterocapus sp.* (Dipterocarpaceae)	P12	8
			Fragraea fragrans Roxd. (Gentianaceae)	P15	44
			Theobroma cacao L. (Malvaceae)	P16	32
			Sandoricum koetjape Merr. (Meliaceae)	P19	15
			Azadirachta indica A. Juss. (Meliaceae)	P21	26
	A23	unidentified sp.2 (Drosophilidae)	*Parkia speciosa* Hassk. (Fabaceae)	P14	9
			Artocarpus heterophyllus Lam. (Moraceae)	P23	24
			Musa sapientum L.(Musaceae)	P24	19
			Clausena cambodiana Guill. (Rutaceae)	P28	17
	A24	Sarcophaga spp (Drosophilidae)	*Mangifera indica* L. (Anacardiaceae)	P1	18
			Garcinia mangostana L. (Clusiaceae)	P11	18
			Parkia speciosa Hassk. (Fabaceae)	P14	18

			Theobroma cacao L. (Malvaceae)	P16	21
			Sandoricum koetjape Merr. (Meliaceae)	P19	26
	A25	Hermetia sp. (Stratiomyidae)	*Mangifera indica* L. (Anacardiaceae)	P1	16
			Sandoricum koetjape Merr. (Meliaceae)	P19	18
			Azadirachta indica A. Juss. (Meliaceae)	P21	45
			Musa sapientum L.(Musaceae)	P24	24
			Citrus aurantifolia Swingle. (Rutaceae)	P29	21
			Citrus (Rutaceae)	P30	21
			Etlingera elatior (Jack.) R.M. Smith. (Zingiberaceae)	P35	16
	A26	Ptecticus sp. (Stratiomyidae)	*Mangifera indica* L. (Anacardiaceae)	P1	28
			Dipterocapus sp. (Dipterocarpaceae)	P12	10
			Sandoricum koetjape Merr. (Meliaceae)	P19	27
			Azadirachta indica A. Juss. (Meliaceae)	P21	37
			Clausena cambodiana Guill. (Rutaceae)	P28	14
	A27	tratiomys sp. (Stratiomyidae)	*Zalacca edulis* Reinw. (Arecaceae)	P3	21

			Areca catechu L. (Arecaceae)	P5	18
			Sandoricum koetjape Merr. (Meliaceae)	P19	16
	A28	Unidentified sp. (Stratiomyidae)	*Theobroma cacao* L. (Malvaceae)	P16	25
			Sandoricum koetjape Merr. (Meliaceae)	P19	29
			Capsicum frutescens L. (Solanaceae)	P34	16
	A29	*Eristalis arvorum* Fabricius (Syrphidae)	*Parkia speciosa* Hassk. (Fabaceae)	P14	20
			Garcinia mangostana L.(Clusiaceae)	P11	20
			Sandoricum koetjape Merr. (Meliaceae)	P19	27
			Azadirachta indica A. Juss. (Meliaceae)	P21	39
			Citrus aurantifolia Swingle. (Rutaceae)	P29	15
			Citrus (Rutaceae)	P30	25
	A30	Eristalis obscuritarsis Meijere (Syrphidae)	*Ananas comosus* (L.) Merr. (Bromeliaceae)	P8	15
			Dipterocapus sp. (Dipterocarpaceae)	P12	21
			Parkia speciosa Hassk. (Fabaceae)	P14	17
			Sandoricum koetjape Merr. (Meliaceae)	P19	16

	A31	Helophilus bengaliensis Wiedemann (Syrphidae)	*Areca catechu* L. (Arecaceae)	P5	21
			Fragraea fragrans Roxd. (Gentianaceae)	P15	37
			Theobroma cacao L. (Malvaceae)	P16	38
			Ceiba pentandra (L.) Gaerth. (Malvaceae)	P18	21
			Sandoricum koetjape Merr. (Meliaceae)	P19	8
			Musa sapientum L. (Musaceae)	P24	19
			Clausena cambodiana Guill. (Rutaceae)	P28	21
	A32	Physocephala sp. (Syrphidae)	*Azadirachta indica* A. Juss. (Meliaceae)	P21	42
			Artocarpus heterophyllus Lam. (Moraceae)	P23	17
			Musa sapientum L. (Musaceae)	P24	20
			Etlingera elatior (Jack.) R.M. Smith.	P35	18
	A33	Rhingia sp.3 (Syrphidae)	*Azadirachta indica* A. Juss. (Meliaceae)	P21	38
			Musa sapientum L. (Musaceae)	P24	24
			Morinda citrifolia (Rubiaceae)	P27	23
	A34	Syrphus sp.1 (Syrphidae)	*Theobroma cacao* L. (Malvaceae)	P16	21

			Azadirachta indica A. Juss. (Meliaceae)	P21	25
			Musa sapientum L. (Musaceae)	P24	31
	A35	Syrphus sp.2 (Syrphidae)	*Garcinia mangostana* L.(Clusiaceae)	P11	15
			Fragraea fragrans Roxd. (Gentianaceae)	P15	28
			Musa sapientum L. (Musaceae)	P24	16
			Citrus aurantifolia Swingle. (Rutaceae)	P29	16
			Manilkara zapota (L.) Van Royen. (Sapotaceae)	P32	7
	A36	Chrysops fasciata Wiedemann (Syrphidae)	*Musa sapientum* L. (Musaceae)	P24	20
			Capsicum frutescens L (Solanaceae)	P34	6
	A37	Tachinidae Drino sp.1 (Syrphidae)	*Musa sapientum* L. (Musaceae)	P24	20
	A38	unidentified sp. (Tephritidae)	*Durio zibethinus* L. (Bombacaceae)	P7	20
			Musa sapientum L. (Musaceae)	P24	16
	A39	Clavigralla sp. (Coreidae)			
			Mangifera indica L. (Anacardiaceae)	P1	8

			Dipterocapus sp. (Dipterocarpaceae)	P12	31
			Azadirachta indica A. Juss. (Meliaceae)	P21	13
			Musa sapientum L. (Musaceae)	P21	25
			Citrus (Rutaceae)	P30	8
			Nephelium lappaceum L. (Sapindaceae)	P31	7
			Capsicum frutescens L. (Solanaceae)	P34	17
	A40	unidentified sp.2 (Coreidae)	*Mangifera indica* L. (Anacardiaceae)	P1	30
			Zalacca edulis Reinw. (Arecaceae)	P3	17
			Areca catechu L. (Arecaceae)	P5	21
			Durio zibethinus L. (Bombacaceae)	P7	25
			Ananas comosus (L.) Merr. (Bromeliaceae)	P8	12
			Cassia siamea Lamk. (Caesalpiniaceae)	P9	14
			Garcinia mangostana L. (Clusiaceae)	P11	32
			Dipterocapus sp. (Dipterocarpaceae)	P12	57
			Theobroma cacao L. (Malvaceae)	P16	26

			Microcos tomentosa Smith. (Malvaceae)	P17	23
			Ceiba pentandra (L.) Gaerth. (Malvaceae)	P18	19
			Azadirachta indica A. Juss. (Meliaceae)	P21	46
			Artocarpus heterophyllus Lam. (Moraceae)	P23	56
			Musa sapientum L. (Musaceae)	P24	19
			Clausena cambodiana Guill. (Rutaceae)	P28	22
			Citrus aurantifolia Swingle. (Rutaceae)	P29	48
			Citrus (Rutaceae)	P30	12
			Nephelium lappaceum L. (Sapindaceae)	P31	13
			Capsicum frutescens L. (Solanaceae)	P34	56
			Alpinia galanga (L.) Willd. (Zingiberaceae)	P36	22
	A41	*Eocanthecona furcellata* Wolff (Pentatomidae)	*Mangifera indica* L. (Anacardiaceae)	P1	26
			Zalacca edulis Reinw. (Arecaceae)	P3	29
			Garcinia mangostana L. (Clusiaceae)	P11	17
			Theobroma cacao L. (Malvaceae)	P16	31

			Azadirachta indica A. Juss. (Meliaceae)	P21	30
			Musa sapientum L. (Musacaceae)	P24	19
			Citrus aurantifolia Swingle. (Rutaceae)	P29	31
	A42	Rhynocoris sp.1 (Pentatomidae)	*Mangifera indica* L.(Anacardiaceae)	P1	9
			Cassia siamea Lamk. (Caesalpiniaceae)	P9	16
			Dipterocapus sp. (Bombacaceae)	P12	42
			Parkia speciosa Hassk. (fabaceae)	P14	17
			Artocarpus heterophyllus Lam. (Moraceae)	P23	43
			Musa sapientum L. (Musaceae)	P24	25
			Morinda citrifolia (Rubiaceae)	P27	31
			Citrus aurantifolia Swingle. (Rutaceae)	P29	34
			Citrus (Rutaceae)	P30	8
			Manilkara zapota (L.) Van Royen. (Sapotaceae)	P32	8
			Capsicum frutescens L. (Solanaceae)	P34	25
			Etlingera elatior (Jack.) R.M. Smith.	P35	25

			(Zingiberaceae)		
			Alpinia galanga (L.) Willd. (Zingiberaceae)	P36	19
	A43	unidentified sp. (Pentatomidae)	*Mangifera indica* L. (Anacardiaceae)	P1	9
			Musa sapientum L. (Musaceae)	P24	25
			Capsicum frutescens L. (Solanaceae)	P34	25
	A44	Callidea sp. (Scutelleridae)	*Mangifera indica* L. (Anacardiaceae)	P1	7
			Dipterocapus sp. (Dipterocarpaceae)	P12	15
			Musa sapientum L. (Musaceae)	P24	28
	A45	Amegilla sp (Anthophprini)	*Mangifera indica* L. (Anacardiaceae)	P1	9
			Musa sapientum L. (Musaceae)	P24	31
			Citrus aurantifolia Swingle. (Rutaceae)	P29	7
			Capsicum frutescens L. (Solanaceae)	P34	17
	A46	*Apis cerana* (Apidae)	*Mangifera foetida* Lour. (Anacardiaceae)	P2	12
			Zalacca edulis Reinw. (Arecaceae)	P3	31
			Cocos nucifera L. (Arecaceae)	P4	10

			Durio zibethinus L. (Bombacaceae)	P7	35
			Ananas comosus (L.) Merr. (Bromeliaceae)	P8	16
			Dipterocapus sp. (Dipterocarpaceae)	P12	31
			Parkia speciosa Hassk. (Fabaceae)	P14	21
			Azadirachta indica A. Juss. (Meliaceae)	P21	53
			Musa sapientum L. (Musaceae)	P24	25
			Syzygium samarangense (Myrtaceae)	P25	15
			Syzygium malaccense Merr & Perry (Myrtaceae)	P26	36
			Morinda citrifolia (Rubiaceae)	P27	46
			Clausena cambodiana Guill. (Rutaceae)	P28	17
			Citrus (Rutaceae)	P30	19
			Nephelium lappaceum L. (Sapindaceae)	P31	38
			Capsicum frutescens L. (Solanaceae)	P34	26
	A47	Apis mellifera ligustica Linnaeus (Apidae)	*Durio zibethinus* L. (Bombacaceae)	P7	42
			Carica papaya L. (Caricaceae)	P10	20

			Parkia speciosa Hassk. (Fabaceae)	P14	16
			Microcos tomentosa Smith. (Malvaceae)	P17	26
			Sandoricum koetjape (Burm.f.) Merr. (Meliaceae)	P19	26
			Azadirachta indica A. Juss. (Meliaceae)	P21	44
			Musa sapientum L. (Musacaceae)	P24	16
			Syzygium samarangense (Myrtaceae)	P25	14
			Citrus aurantifolia Swingle. (Rutaceae)	P29	27
			Nephelium lappaceum L. (Sapindaceae)	P31	42
			Etlingera elatior (Jack.) R.M. Smith. (Zingiberaceae)	P35	26
			Alpinia galanga (L.) Willd. (Zingiberaceae)	P36	16
	A48	*Apis dorsata* (Apidae)	*Durio zibethinus* L. (Bombacaceae)	P7	44
			Dipterocapus sp. (Dipterocarpaceae)	P12	25
			Sandoricum koetjape (Burm.f.) Merr. (Meliaceae)	19	18
			Azadirachta indica A. Juss. (Meliaceae)	P21	35

			Artocarpus heterophyllus Lam. (Moraceae)	P23	28
			Musa sapientum L. (Musaceae)	P24	28
			Syzygium malaccense Merr & Perry (Myrtaceae)	P26	26
			Morinda citrifolia (Rubiaceae)	P27	51
			Nephelium lappaceum L. (Sapindaceae)	P31	19
			Capsicum frutescens L. (Solanaceae)	P34	29
	A49	*Pithitis smaragudla* Fabricius (Apidae)	*Areca catechu* L. (Arecaceae)	P5	18
			Garcinia mangostana L. (Clusiaceae)	P11	17
			Parkia speciosa Hassk. (Fabaceae)	P14	24
			Fragraea fragrans Roxd. (Gentianaceae)	P15	29
			Theobroma cacao L. (Malvaceae)	P16	31
			Microcos tomentosa Smith. (Malvaceae)	P17	32
			Sandoricum koetjape (Burm.f.) Merr. (Meliaceae)	P19	27
			Azadirachta indica A. Juss. (Meliaceae)	P21	56

			Musa sapientum L. (Musaceae)	P24	25
			Clausena cambodiana Guill. (Rutaceae)	P28	28
			Citrus aurantifolia Swingle. (Rutaceae)	P29	21
			Citrus (Rutaceae)	P30	21
			Nephelium lappaceum L. (Sapindaceae)	P31	5
			Alpinia galanga (L.) Willd. (Zingiberaceae)	P36	25
	A50	*Podalirius crocea* Bingham (Apidae)	*Zalacca edulis* Reinw. (Arecaceae)	P3	22
			Carica papaya L. (Caricaceae)	P10	12
			Dipterocapus sp. (Dipterocarpaceae)	P12	46
			Sandoricum koetjape (Burm.f.) Merr. (Meliaceae)	P19	16
			Azadirachta indica A. Juss. (Meliaceae)	P21	43
			Musa sapientum L. (Musaceae)	P24	31
			Morinda citrifolia (Rubiaceae)	P27	32
			Nephelium lappaceum L. (Sapindaceae)	P31	10
	A51	Thyreus sp. (Apidae)	*Sandoricum koetjape* (Burm.f.) Merr.	P19	29

			(Meliaceae)		
			Azadirachta indica A. Juss. (Meliaceae)	P21	65
			Musa sapientum L. (Musaceae)	P24	5
			Clausena cambodiana Guill. (Rutaceae)	P28	24
			Citrus aurantifolia Swingle. (Rutaceae)	P29	19
			Nephelium lappaceum L. (Sapindaceae)	P31	16
			Capsicum frutescens L. (Solanaceae)	P34	34
			Etlingera elatior (Jack.) R.M. Smith. (Zingiberaceae)	P35	12
	A52	*Trigona ventralis* Smith (Apidae)	*Dipterocapus sp.* (Dipterocarpaceae)	P12	32
			Fragraea fragrans Roxd. (Gentianaceae)	P15	26
			Theobroma cacao L. (Malvaceae)	P16	26
			Sandoricum koetjape (Burm.f.) Merr. (Meliaceae)	P19	27
			Azadirachta indica A. Juss. (Meliaceae)	P21	40
			Musa sapientum L. (Musaceae)	P24	30

			Syzygium samarangense (Myrtaceae)	P25	13
			Morinda citrifolia (Rubiaceae)	P27	21
			Nephelium lappaceum L. (Sapindaceae)	P31	39
			Alpinia galanga (L.) Willd. (Zingiberaceae)	P36	16
	A53	*Trigona collina* Smith (Apidae)	*Garcinia mangostana* L. (Clusiaceae)	P11	21
			Microcos tomentosa Smith. (Malvaceae)	P17	14
			Sandoricum koetjape (Burm.f.) Merr. (Meliaceae)	P19	16
			Artocarpus heterophyllus Lam. (Moraceae)	P23	21
			Musa sapientum L. (Musaceae)	P24	34
			Citrus aurantifolia Swingle. (Rutaceae)	P29	14
			Nephelium lappaceum L. (Sapindaceae)	P31	56
	A54	*Trigona melanoleuca* Cockerell (Apidae)	*Dipterocapus sp.* (Dipterocarpaceae)	P12	17
			Fragraea fragrans Roxd. (Gentianaceae)	P15	21
			Sandoricum koetjape (Burm.f.) Merr. (Meliaceae)	P19	36

			Musa sapientum L. (Musaceae)	P24	30
			Clausena cambodiana Guill. (Rutaceae)	P28	32
			Nephelium lappaceum L. (Sapindaceae)	P31	18
			Capsicum frutescens L. (Solanaceae)	P34	42
	A55	*Trigana erythrogasta* (Apidae)	*Zalacca edulis* Reinw. (Arecaceae)	P3	33
			Dipterocapus sp. (Dipterocarpaceae)	P12	41
			Nephelium lappaceum L. (Sapindaceae)	P19	12
			Musa sapientum L. (Musaceae)	P24	28
			Citrus aurantifolia Swingle. (Rutaceae)	P29	17
			Manilkara zapota (L.) Van Royen. (Sapotaceae)	P32	9
			Etlingera elatior (Jack.) R.M. Smith. (Zingiberaceae)	P35	23
	A56	*Hypotrigona scintillans* (Apidae)	*Ceiba pentandra* (L.) Gaerth. (Malvaceae)	P18	20
			Nephelium lappaceum L. (Sapindaceae)	P19	15
			Musa sapientum L. (Musaceae)	P24	18

	A57	*Trigona itama* (Apidea)	*Durio zibethinus* L. (Bombacaceae)	P7	12
			Parkia speciosa Hassk. (Fabaceae)	P14	9
			Theobroma cacao L. (Malvaceae)	P16	1
			Artocarpus heterophyllus Lam. (Moraceae)	P23	14
			Musa sapientum L. (Musaceae)	P24	23
			Nephelium lappaceum L. (Sapindaceae)	P31	11
			Capsicum frutescens L. (Solanaceae)	P34	7
	A58	*Trigona peninsularis* (Apidae)	*Areca catechu* L. (Arecaceae)	P5	21
			Fragraea fragrans Roxd. (Gentianaceae)	P15	8
			Azadirachta indica A. Juss. (Meliaceae)	P21	12
			Musa sapientum L. (Musaceae)	P24	26
			Citrus aurantifolia Swingle. (Rutaceae)	P29	6
			Nephelium lappaceum L. (Sapindaceae)	P31	6
	A59	*Trigona apicalis* (Apidae)	*Dipterocapus sp.* (Dipterocarpaceae)	P12	4
			Sandoricum koetjape (Burm.f.) Merr. (Meliaceae)	P19	13

			Nephelium lappaceum L. (Sapindaceae)	P31	10
			Manilkara zapota (L.) Van Royen. (Sapotaceae)	P32	8
	A60	*Trigona canifrons* (Apidae)	*Fragraea fragrans* Roxd. (Gentianaceae)	P15	15
			Ceiba pentandra (L.) Gaerth. (Malvaceae)	P18	23
			Musa sapientum L. (Musaceae)	P24	26
			Nephelium lappaceum L. (Sapindaceae)	P31	7
	A61	*Trigona thoracica* (Apidae)	*Areca catechu* L. (Arecaceae)	5	17
			Garcinia mangostana L. (Clusiaceae)	P11	5
			Musa sapientum L. (Musaceae)	P24	18
			Nephelium lappaceum L. (Sapindaceae)	P31	11
			Etlingera elatior (Jack.) R.M. Smith. (Zingiberaceae)	P35	[illegible]
	A62	*Xylocopa collaris* Cockerell (Apidae)	*Sandoricum koetjape* (Burm.f.) Merr. (Meliaceae)	P19	17
			Musa sapientum L. (Musaceae)	P24	18
			Nephelium lappaceum L. (Sapindaceae)	P31	7

	A63	*Xylocopa aestuans* Linnaeus (Apidae)	*Musa sapientum* L. (Musaceae)	P24	18
			Nephelium lappaceum L. (Sapindaceae)	P31	8
	A64	*Xylocopa nasalis* (Apidae)	*Microcos tomentosa* Smith. (Malvaceae)	P17	15
			Azadirachta indica A. Juss. (Meliaceae)	P21	22
			Musa sapientum L. (Musaceae)	P24	23
			Nephelium lappaceum L. (Sapindaceae)	P31	6
			Etlingera elatior (Jack.) R.M. Smith. (Zingiberaceae)	P35	8
	A65	*Xylocopa tranquebarica* (Apidae)	*Durio zibethinus* L. (Bombacaceae)	P7	9
			Musa sapientum L. (Musaceae)	P24	23
			Nephelium lappaceum L. (Sapindaceae)	P31	9
	A66	*Xylocopa tenuiscapa* (Apidae)	*Ceiba pentandra* (L.) Gaerth.	P18	7
			Sandoricum koetjape (Burm.f.) Merr.	P19	5
			Artocarpus heterophyllus Lam.	P23	18
			Citrus aurantifolia Swingle.	P29	8
			Capsicum frutescens L.	P34	18

	A67	Stilbum sp. (Apidae)	*Areca catechu* L. (Arecaceae)	P5	8
			Garcinia mangostana L. (Clusiaceae)	P11	12
			Fragraea fragrans Roxd. (Gentianaceae)	P15	21
			Musa sapientum L. (Musaceae)	2P4	17
			Nephelium lappaceum L. (Sapindaceae)	P31	8
	A68	Camponotus sp.1 (Apidae)	*Mangifera indica* L. (Anacardaceae)	P1	9
			Dipterocapus sp. (Dipterocarpaceae)	P12	12
			Sandoricum koetjape (Burm.f.) Merr. (Meliaceae)	P19	21
			Nephelium lappaceum L. (Sapindaceae)	P31	7
	A69	*Oecophylla smaracdina* Fabricius (Apidae)	*Sandoricum koetjape* (Burm.f.) Merr. (Meliaceae)	P19	19
			Azadirachta indica A. Juss. (Meliceae)	P21	15
			Nephelium lappaceum L. (Sapindaceae)	P31	8
	A70	Paratrechina sp.1 (Apidae)	*Mangifera indica* L. (Anacardaceae)	P1	10
			Musa sapientum L. (Musaceae)	P24	23

	A71	Paratrechina sp.2 (Apidae)	*Mangifera indica* L. (Anacardaceae)	P1	10
			Parkia speciosa Hassk. (Fabaceae)	P14	8
	A72	Paratrechina sp.2 (Apidae)	*Mangifera indica* L. (Anacardaceae)	1	11
			Sandoricum koetjape (Burm.f.) Merr. (Meliaceae)	P19	5
			Musa sapientum L. (Musaceae)	P24	17
	A73	unidentified sp. (Apidae)	*Mangifera indica* L. (Anacardaceae)	P1	6
			Sandoricum koetjape (Burm.f.) Merr. (Meliaceae)	P19	9
	A74	Halictus sp.1 (Halictidae)	*Mangifera indica* L. (Anacardaceae)	P1	7
			Musa sapientum L. (Musaceae)	P24	17
	A75	Coelioxys sp. (Megachilidae)	*Mangifera indica* L. (Anacardaceae)	P1	7
			Musa sapientum L. (Musaceae)	P24	33
	A76	Euaspis sp.1 (Megachilidae)	*Mangifera indica* L. (Anacardaceae)	P1	10
			Musa sapientum L. (Musaceae)	P24	30
	A77	Lithurge sp. (Megachilidae)	*Mangifera indica* L. (Anacardaceae)	P1	10

			Musa sapientum L. (Musaceae)	P24	29
	A78	*Megachile disjuncta* Fabricius (Apidae)	*Mangifera indica* L. (Anacardaceae)	P1	9
			Musa sapientum L. (Musaceae)	P24	30
			Capsicum frutescens L. (Solanaceae)	P34	21
			Etlingera elatior (Jack.) R.M. Smith. (Zingiberaceae)	P35	11
	A79	*Megachile* sp.3 (Apidae)	*Durio zibethinus* L. (Bombacaceae)	P7	11
			Carica papaya L. (Caricaceae)	P10	6
			Fragraea fragrans Roxd. (Gentianaceae)	P15	10
			Musa sapientum L. (Musaceae)	P24	29
			Clausena cambodiana Guill. (Rutaceae)	P28	15
			Alpinia galanga (L.) Willd. (Zingiberaceae)	P36	19
	A80	*Megachile* sp.9 (Apidae)	*Cocos nucifera* L. (Arecaceae)	P4	15
			Carica papaya L. (Caricaceae)	P10	5
			Dipterocapus sp. (Dipterocarpaceae)	P12	9
			Parkia speciosa Hassk. (Fabaceae)	P14	19

			Artocarpus integer (Thunb.) Merr. (Moraceae)	P22	9
			Musa sapientum L. (Musaceae)	P24	27
			Capsicum frutescens L. (Solanaceae)	P34	12
	A81	*Megachile* sp.10 (Apidae)	*Carica papaya* L. (Caricaceae)	P10	11
			Musa sapientum L. (Musaceae)	P24	27
			Syzygium samarangense (Myrtaceae)	P25	9
	A82	*Megachile* sp.14 (Apidae)	*Zalacca edulis* Reinw. (Arecaceae)	P3	10
			Ananas comosus (L.) Merr. (Bromeliaceae)	P8	7
			Carica papaya L. (Caricaceae)	P10	10
			Musa sapientum L. (Musaceae)	P24	33
	A83	*Trogaspidia sp.* (Mutillidae)	*Carica papaya* L. (Caricaceae)	P10	12
			Parkia speciosa Hassk. (Fabaceae)	P14	21
			Fragraea fragrans Roxd. (Gentianaceae)	P15	11
			Artocarpus heterophyllus Lam. (Moraceae)	P23	9
			Musa sapientum L. (Musaceae)	P24	30

			Clausena cambodiana Guill. (Rutaceae)	P28	14
	A84	*Camsomeris collaris* (Scoliidae)	*Carica papaya* L. (Caricaceae)	P10	8
			Microcos tomentosa Smith. (Malvaceae)	P17	16
			Musa sapientum L. (Musaceae)	P24	29
			Alpinia galanga (L.) Willd. (Zingiberaceae)	P36	15
	A85	*Scolia* sp.3 (Scoliidae)	*Carica papaya* L. (Caricaceae)	P10	8
			Musa sapientum L. (Musaceae)	P24	27
	A86	unidentified sp.3 (Scoliidae)	*Carica papaya* L. (Caricaceae)	P10	9
			Dipterocapus sp. (Dipterocarpaceae)	P12	12
			Musa sapientum L. (Musaceae)	P24	24
			Nephelium lappaceum L. (Sapindaceae)	P31	10
	A87	Chlorion sp.1 (Scoliidae)	*Musa sapientum* L. (Musaceae)	P24	21
			Nephelium lappaceum L. (Sapindaceae)	P31	10
	A88	Vespa sp.1 (Scoliidae)	*Fragraea fragrans* Roxd. (Gentianaceae)	P15	7
			Musa sapientum L. (Musaceae)	P24	24

			Clausena cambodiana Guill. (Rutaceae)	P28	18
			Nephelium lappaceum L. (Sapindaceae)	P31	11
	A89	Vespa sp.2 (Scoliidae)	*Musa sapientum* L. (Musaceae)	P24	21
			Nephelium lappaceum L. (Sapindaceae)	P31	21
	A90	*Amata sperbius* Fabricius (Arctiidae)	*Cocos nucifera* L. (Arecaceae)	P4	20
			Microcos tomentosa Smith. (Malvaceae)	P17	16
			Musa sapientum L. (Musaceae)	P24	24
			Nephelium lappaceum L. (Sapindaceae)	P31	18
	A91	*Euchromia elegantissima* Wallgram (Arctiidae)	*Durio zibethinus* L. (Bombacaceae)	P7	20
			Parkia speciosa Hassk. (Fabaceae)	P14	16
			Musa sapientum L. (Musaceae)	P24	21
			Nephelium lappaceum L. (Sapindaceae)	P31	15
	A92	D. chrysippus (Danaidae)	*Musa sapientum* L. (Musaceae)	P24	23
			Nephelium lappaceum L. (Sapindaceae)	P31	19
	A93	*Amblypodia anita anita* Hewitson	*Microcos tomentosa* Smith. (Malvaceae)	P17	10

		(Lycaenidae)			
			Artocarpus heterophyllus Lam. (Moraceae)	P23	6
			Musa sapientum L. (Musaceae)	P24	28
			Clausena cambodiana Guill. (Rutaceae)	P28	21
			Nephelium lappaceum L. (Sapindaceae)	P31	20
			Capsicum frutescens L. (Solanaceae)	P34	9
	A94	Loxura atymnus continentalis Fruhstofer (Lycaenidae)	*Fragraea fragrans* Roxd. (Gentianaceae)	P15	6
			Artocarpus integer (Thunb.) Merr. (Moraceae)	P22	12
			Musa sapientum L. (Musaceae)	P24	23
			Nephelium lappaceum L. (Sapindaceae)	P31	15
	A95	Cirrochoa tyche mithila Moore (Lycaenidae)	*Durio zibethinus* L. (Bombacaceae)	P7	14
			Ananas comosus (L.) Merr. (Bromeliaceae)	P8	6
			Musa sapientum L. (Musaceae)	P24	28
			Nephelium lappaceum L. (Sapindaceae)	P31	22

	A96	Junonia sp. (Lycaenidae)	*Durio zibethinus* L. (Bombacaceae)	P7	18
			Parkia speciosa Hassk. (Fabaceae)	P14	21
			Azadirachta indica A. Juss. (Meliceae)	P21	8
			Nephelium lappaceum L. (Sapindaceae)	P31	17
	A97	Neptis hylas kamarupa Moore (Lycaenidae)	*Dipterocapus sp.* (Dipterocarpaceae)	P12	8
			Fragraea fragrans Roxd. (Gentianaceae)	P15	9
			Musa sapientum L. (Musaceae)	P24	23
			Nephelium lappaceum L. (Sapindaceae)	P31	26
	A98	Lamproptera meges virescens (Butler) (Lycaenidae)	*Musa sapientum* L. (Musaceae)	P24	28
			Nephelium lappaceum L. (Sapindaceae)	P31	16
			Alpinia galanga (L.) Willd. (Zingiberaceae)	P36	21
	A99	Pathysa antiphates pompilius (Lycaenidae)	*Musa sapientum* L. (Musaceae)	P24	30

			Syzygium samarangense (Myrtaceae)	P25	5
	A100	Eurema sp. (Lycaenidae)	*Microcos tomentosa* Smith. (Malvaceae)	P17	9
			Musa sapientum L. (Musaceae)	P24	20
			Nephelium lappaceum L. (Sapindaceae)	P31	33
	A101	unidentified sp.2 (Lycaenidae)	*Musa sapientum* L. (Musaceae)	P24	30
			Nephelium lappaceum L. (Sapindaceae)	P31	18
	A102	Melitta sp.3 (Lycaenidae)	*Musa sapientum* L. (Musaceae)	P24	20
			Nephelium lappaceum L. (Sapindaceae)	P31	29
	A103	Mantis religiosa Linnaeus (Mantidae)	*Musa sapientum* L. (Musaceae)	P24	30
			Nephelium lappaceum L. (Sapindaceae)	P31	20
	A104	unidentified sp. (Mantidae)	*Musa sapientum* L. (Musaceae)	P24	20
	A105	Eonycteris speleae	*Oroxylum indicum* Vent. (Bignoniaceae)	P6	78
			Durio zibethinus L. (Bombacaceae)	P7	76
			Parkia speciosa Hassk. (Fabaceae)	P14	57
			Musa sapientum L. (Musaceae)	P24	51

	A106	C.sphinx	*Durio zibethinus* L. (Bombacaceae)	P7	25
			Parkia speciosa Hassk. (Fabaceae)	P14	25
			Musa sapientum L. (Musaceae)	P24	84
	A107	C.horsfidii	*Parkia speciosa* Hassk. (Fabaceae)	P14	30
	A108	M.minimus	*Durio zibethinus* L. (Bombacaceae)	P7	34
			Parkia speciosa Hassk. (Fabaceae)	P14	16
			Musa sapientum L. (Musaceae)	P24	70
	A109	M. sobrinus	*Durio zibethinus* L. (Bombacaceae)	P7	20
			Parkia speciosa Hassk. (Fabaceae)	P14	14
			Musa sapientum L. (Musaceae)	P24	62

Table 4.1 Interaction of plant and pollinator from one study site far from forest

Animal group	ID	Animal species	Plant species	Plant ID	Number of visits
Beatles	A1	Chlorophorus annularis Fabricius	*Sandoricum koetjape* (Burm.f.) Merr. (Meliaceae)	P12	63
			Citrus aurantifolia Swingle. (Rotaceae)	P23	15
			Nephelium lappaceum L. (Sapindaceae)	P24	32
	A2	Ixorida mouhotii Wallace	*Garcinia mangostana* L. (Clusiaceae)	P8	3
			Citrus hystrix DC. (Rotaceae)	P22	9
			Nephelium lappaceum L. (Sapindaceae)	P24	26
	A3	unidentified sp.	*Carica papaya* L. (Caricaceae)	P7	28
			Citrus aurantifolia Swingle. (Rotaceae)	P23	9
			Nephelium lappaceum L. (Sapindaceae)	P24	25
	A4	Promachus sp.	*Sandoricum koetjape* (Burm.f.) Merr. (Meliaceae)	P12	12
			Citrus hystrix DC. (Rotaceae)	P22	7
	A5	Chrysomyia sp.1	*Lansium domesticum* L.(Meliaceae)	P13	19
			Citrus hystrix DC. (Rotaceae)	P22	4

			Nephelium lappaceum L. (Sapindaceae)	P24	31
	A6	Chrysomyia sp.2	*Carica papaya* L. (Caricaceae)	P7	23
			Sandoricum koetjape (Burm.f.) Merr. (Meliaceae)	P12	25
			Citrus aurantifolia Swingle. (Rotaceae)	P23	14
			Nephelium lappaceum L. (Sapindaceae)	P24	47
	A7	Hypopygropsis sp.	*Garcinia mangostana* L. (Clusiaceae)	P8	12
			Nephelium lappaceum L. (Sapindaceae)	P24	46
	A8	Drosophila sp.	*Sandoricum koetjape* (Burm.f.) Merr. (Meliaceae)	P12	47
			Citrus hystrix DC. (Rotaceae)	P22	8
	A9	unidentified sp.4	*Nephelium lappaceum* L. (Sapindaceae)	P24	64
	A10	Parasarcophaga sp.	*Annona squamosa* L. (Annonaceae)	P3	12
			Nephelium lappaceum L. (Sapindaceae)	P24	54
			Solanum torvum SW. (Solanaceae)	P27	4
	A11	Ptecticus sp.	*Garcinia mangostana* L. (Clusiaceae)	P8	11
			Citrus hystrix DC. (Rotaceae)	P22	8

			Nephelium lappaceum L. (Sapindaceae)	P24	38
	A12	Unidentified sp.	*Bouea microphylla* Griff. (Anacardiaceae)	P1	8
			Baccaurea ramiflora Lour. (Euphorbiaceae)	P9	15
			Lansium domesticum L.(Meliaceae)	P13	31
			Azadirachta indica A. Juss. (Meliaceae)	P15	39
			Nephelium lappaceum L. (Sapindaceae)	P24	67
	A13	Eristalis arvorum (Fabricius)	*Cocos nucifera* L. (Arecaceae)	P4	18
			Citrus hystrix DC. (Rotaceae)	P22	11
			Nephelium lappaceum L. (Sapindaceae)	P24	46
	A14	Eristalis obscuritarsis Meijere	Garcinia mangostana L. (Clusiaceae)	P8	15
			Musa sapientum L. (Musaceae)	P17	31
	A15	Helophilus bengaliensis Wiedemann	*Azadirachta indica* A. Juss. (Meliaceae)	P15	43
			Musa sapientum L. (Musaceae)	P17	27
			Syzygium cumini L. (Musaceae)	P20	46
			Citrus hystrix DC. (Rotaceae)	P22	5

	A16	Helophilus sp.1	*Bouea microphylla* Griff. (Anacardiaceae)	P1	12
			Garcinia mangostana L. (Clusiaceae)	P8	8
			Musa sapientum L. (Musaceae)	P17	29
			Citrus hystrix DC. (Rotaceae)	P22	7
	A17	Helophilus sp.2	*Lansium domesticum* L.(Meliaceae)	P13	25
			Azadirachta indica A. Juss. (Meliaceae)	P15	18
			Musa sapientum L. (Musaceae)	P17	25
			Syzygium cumini L. (Musaceae)	P20	54
			Citrus hystrix DC. (Rotaceae)	P22	14
			Solanum torvum SW. (Solanaceae)	P27	5
	A18	Megapis sp.	*Baccaurea ramiflora* Lour. (Euphorbiaceae)	P9	10
			Musa sapientum L. (Musaceae)	P17	24
			Nephelium lappaceum L. (Sapindaceae)	P24	48
			Dimocarpus longan Lour. (Sapindaceae)	P25	18
	A19	Physocephala sp.	*Cocos nucifera* L. (Arecaceae)	P4	23

			Azadirachta indica A. Juss. (Meliaceae)	P15	35
			Musa sapientum L. (Musaceae)	P17	27
	A20	Rhingia sp.1	*Bouea microphylla* Griff. (Anacardiaceae)	P1	27
			Garcinia mangostana L. (Clusiaceae)	P8	13
			Lansium domesticum L.(Meliaceae)	P13	39
			Musa sapientum L. (Musaceae)	P17	28
			Citrus hystrix DC. (Rotaceae)	P22	12
	A21	Rhingia sp.2	*Lansium domesticum* Corr. (Meliaceae)	P14	16
			Musa sapientum L. (Musaceae)	P17	31
			Citrus hystrix DC. (Rotaceae)	P22	7
			Nephelium lappaceum L. (Sapindaceae)	P24	40
			Dimocarpus longan Lour. (Sapindaceae)	P25	25
			Solanum torvum SW. (Solanaceae)	P27	9
	A22	Rhingia sp.3	*Lansium domesticum* L.(Meliaceae)	P13	20
			Musa sapientum L. (Musaceae)	P17	26

	A23	Rhingia sp.4	*Musa sapientum* L. (Musaceae)	P17	24
	A24	Graptostethus servus Fabricius	*Nephelium lappaceum* L. (Sapindaceae)	P24	7
	A25	unidentified sp.2	*Citrus hystrix DC. (Rotaceae)*	P22	12
			Nephelium lappaceum L. (Sapindaceae)	P24	5
	A26	Eocanthecona furcellata (Wolff)	*Sandoricum koetjape* (Burm.f.) Merr. (Meliaceae)	P12	9
	A27	Eusarcocoris guttiger Thunberg	*Sandoricum koetjape* (Burm.f.) Merr. (Meliaceae)	P12	7
	A28	Ectomocoris sp.	*Sandoricum koetjape* (Burm.f.) Merr. (Meliaceae)	P12	5
	A29	Rhynocoris sp.1	*Nephelium lappaceum* L. (Sapindaceae)	P24	9
	A30	Amegilla sp	*Musa sapientum* L. (Musaceae)	P17	26
	A31	Apis andreniformis Smith	*Parkia speciosa* Hassk. (Fabaceae)	P11	51
			Musa sapientum L. (Musaceae)	P17	29
	A32	Apis cerana indica Fabricius	*Bouea microphylla* Griff. (Anacardiaceae)	P1	16
			Cocos nucifera L. (Arecaceae)	P4	15
			Durio zibethinus L. (Bombacaceae)	P5	57
			Carica papaya L. (Caricaceae)	P7	31

			Garcinia mangostana L. (Clusiaceae)	P8	17
			Baccaurea ramiflora Lour. (Euphorbiaceae)	P9	31
			Tamarindus indica L. (Fabaceae)	P10	31
			Lansium domesticum Corr. (Meliaceae)	P14	12
			Musa sapientum L. (Musaceae)	P17	27
			Syzygium malaccense Merr & Perry (Musaceae)	P18	32
			Psidium guajava L. (Musaceae)	P19	7
			Citrus hystrix DC. (Rotaceae)	P22	21
			Nephelium lappaceum L. (Sapindaceae)	P24	27
			Capsicum frutescens L. (Solanaceae)	P26	21
			Alpinia galanga (L.) Willd. Zingiberaceae	P28	63
	A33	Apis dorsata Fabricius	*Parkia speciosa* Hassk. (Fabaceae)	P11	16
			Musa sapientum L. (Musaceae)	P17	31
			Syzygium malaccense Merr & Perry (Musaceae)	P18	26
			Capsicum frutescens L. (Solanaceae)	P26	43

	A34	Apis florea Fabricius	*Carica papaya* L. (Caricaceae)	P7	47
			Lansium domesticum L.(Meliaceae)	P13	13
			Lansium domesticum Corr. (Meliaceae)	P14	
			Musa sapientum L. (Musaceae)	P17	30
			Syzygium malaccense Merr & Perry (Musaceae)	P18	25
	A35	Apis mellifera ligustica Linnaeus	*Garcinia mangostana* L. (Clusiaceae)	P8	30
			Musa sapientum L. (Musaceae)	P17	26
			Nephelium lappaceum L. (Sapindaceae)	P24	10
	A36	Hypotrigona scintillans	*Parkia speciosa* Hassk. (Fabaceae)	P11	2
			Azadirachta indica A. Juss. (Meliaceae)	P15	12
			Musa sapientum L. (Musaceae)	P17	21
			Syzygium cumini L. (Musaceae)	P20	15
	A37	Trigona itama	*Cassia siamea* Lamk. (Caesalpiniaceae)	P6	23
			Sandoricum koetjape (Burm.f.) Merr. (Meliaceae)	P12	35
			Musa sapientum L. (Musaceae)	P17	25

			Citrus hystrix DC. (Rotaceae)	P22	21
			Dimocarpus longan Lour. (Sapindaceae)	P25	15
			Capsicum frutescens L. (Solanaceae)	P26	31
	A38	Trigona peninsularis	*Durio zibethinus* L. (Bombacaceae)	P5	[illegible]
			Baccaurea ramiflora Lour. (Euphorbiaceae)	P9	8
			Sandoricum koetjape (Burm.f.) Merr. (Meliaceae)	P12	29
			Lansium domesticum Corr. (Meliaceae)	P14	13
			Musa sapientum L. (Musaceae)	P17	24
			Syzygium samarangense (Musaceae)	P21	9
			Capsicum frutescens L. (Solanaceae)	P26	47
	A39	Trigona apicalis	*Cassia siamea* Lamk. (Caesalpiniaceae)	P6	18
			Parkia speciosa Hassk. (Fabaceae)	P11	18
			Sandoricum koetjape (Burm.f.) Merr. (Meliaceae)	P12	20
			Lansium domesticum L.(Meliaceae)	P13	42
			Azadirachta indica A. Juss. (Meliaceae)	P15	25

			Musa sapientum L. (Musaceae)	P17	20
			Syzygium cumini L. (Musaceae)	P20	27
			Citrus aurantifolia Swingle. (Rotaceae)	P23	14
			Capsicum frutescens L. (Solanaceae)	P26	46
	A40	Trigona canifrons	*Annona squamosa* L. (Annonaceae)	P3	
			Garcinia mangostana L. (Clusiaceae)	P8	15
			Parkia speciosa Hassk. (Fabaceae)	P11	27
			Sandoricum koetjape (Burm.f.) Merr. (Meliaceae)	P12	42
			Lansium domesticum Corr. (Meliaceae)	P14	21
			Musa sapientum L. (Musaceae)	P17	24
			Psidium guajava L. (Musaceae)	P19	32
			Citrus hystrix DC. (Rotaceae)	P22	34
	A41	Trigona thoracica	*Cocos nucifera* L. (Arecaceae)	P4	19
			Carica papaya L. (Caricaceae)	P7	34
			Tamarindus indica L. (Fabaceae)	P10	15

			Azadirachta indica A. Juss. (Meliaceae)	P15	16
			Musa sapientum L. (Musaceae)	P17	22
			Citrus hystrix DC. (Rotaceae)	P22	53
	A42	Chrysididae Stilbum cyanarum (F?rster)	*Bouea microphylla* Griff. (Anacardiaceae)	P1	19
			Durio zibethinus L. (Bombacaceae)	P5	7
			Cassia siamea Lamk. (Caesalpiniaceae)	P6	39
			Musa sapientum L. (Musaceae)	P17	31
			Citrus hystrix DC. (Rotaceae)	P22	46
			Dimocarpus longan Lour. (Sapindaceae)	P25	24
			Solanum torvum SW. (Solanaceae)	P27	12
	A43	Stilbum sp.	*Baccaurea ramiflora* Lour. (Euphorbiaceae)	P9	12
			Musa sapientum L. (Musaceae)	P17	27
	A44	Vespa sp.2	*Cocos nucifera* L. (Arecaceae)	P4	5
			Musa sapientum L. (Musaceae)	P17	26
	A45	unidentified sp.	*Musa sapientum* L. (Musaceae)	P17	23

			Psidium guajava L. (Musaceae)	P19	7
	A46	Neptis hylas kamarupa Moore	*Garcinia mangostana* L. (Clusiaceae)	P8	24
			Musa sapientum L. (Musaceae)	P17	24
	A47	Lamproptera meges virescens (Butler)	*Musa sapientum* L. (Musaceae)	P17	26
			Citrus hystrix DC. (Rotaceae)	P22	3
	A48	Pachliopta aristolochiae goniopeltis	*Carica papaya* L. (Caricaceae)	P7	29
			Parkia speciosa Hassk. (Fabaceae)	P11	1
			Musa sapientum L. (Musaceae)	P17	24
			Capsicum frutescens L. (Solanaceae)	P26	64
	A49	Eonycteris speleae	*Durio zibethinus* L. (Bombacaceae)	P5	22
			Musa sapientum L. (Musaceae)	P17	15
	A50	R. amplexicaudatus	*Durio zibethinus* L. (Bombacaceae)	P5	10
	A51	C.sphinx	*Durio zibethinus* L. (Bombacaceae)	P5	30
			Musa sapientum L. (Musaceae)	P17	70

	A52	C.brachyotis	*Parkia speciosa* Hassk. (Fabaceae)	P11	9
			Musa sapientum L. (Musaceae)	P17	75
	A53	C.horsfieldi	*Musa sapientum* L. (Musaceae)	P17	80
	A54	M.minimus	*Musa sapientum* L. (Musaceae)	P17	77

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