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Native Bee Pollinators and Pollen Sources of Apidae (Hymenoptera) in Four Forest Types of Lower Northern Thailand

(Pendebunga Lebah Asli dan Sumber Debunga Apidae (Hymenoptera) dalam Empat Jenis Hutan di Hilir Utara Thailand)

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ABSTRACT

Bee species diversity and pollen sources of Apidae (Hymenoptera) in Thung Salaeng Luang National Park, lower northern Thailand, were studied from 2011 to 2012. The forest types encountered were deciduous dipterocarp, deciduous with bamboo, seasonal evergreen and dipterocarp - pine forests. Sweep nets and honey bait traps were used to collect bee samples. The beta diversity of native bees was high with 22 recorded insect species from 12 genera and pollen grains collected by native bees were 62 plant species from 28 families. The plant family Fabaceae (Leguminosae) contained the greatest number of species (9 species). The main pollen source of native bees was Hopea odorata Roxb. (Dipterocarpaceae) *which was collected by 19 bee species. The result from biodiversity indices i.e. species diversity (H'), species evenness (J'), similarity habitat (S_s) and species richness (D) indicated that this area has relatively high species diversity. In addition, the dwarf honey bees,* Apis florea *Fabricius, 1787, are the main pollinator at the study site with the highest number of pollinated plant species (46 species). Thus, this bee could be used as a biological indicator for future studies.*

Keywords: Biodiversity; native bees; seasonal forests; Thailand; vegetation

ABSTRAK

Kepelbagaian spesies lebah dan sumber debunga Apidae (Hymenoptera) di Taman Negara Thung Salaeng Luang, hilir Utara Thailand telah dikaji dari 2011 hingga 2012. Jenis-jenis hutan yang dikenal pasti adalah meluruh dipterokarpa, meluruh dengan buluh, malar hijau bermusim dan dipterokarpa - hutan pain. Jaring sapu dan perangkap umpan madu telah digunakan untuk mengumpul sampel lebah. Kepelbagaian beta lebah asli adalah tinggi dengan 22 spesies serangga yang direkodkan daripada 12 genus dan debunga yang dikumpul oleh lebah asli terdiri daripada 62 spesies tumbuhan daripada 28 keluarga. Keluarga pokok Fabaceae (Leguminosae) mengandungi jumlah spesies paling banyak (9 spesies). Punca utama debunga lebah asli adalah Hopea odorata *Roxb. (*Dipterocarpaceae*) telah dikumpul melalui 19 spesies lebah. Hasil daripada indeks kepelbagaian biologi seperti spesies kepelbagaian (H'), spesies sama (J'), persamaan habitat (S_s) dan kekayaan spesies (D) menunjukkan bahawa kawasan ini mempunyai kepelbagaian spesies yang agak tinggi. Di samping itu, lebah madu kerdil,* Apis florea *Fabricius , 1787, adalah pendebunga utama di tapak kajian dengan jumlah spesies tumbuhan yang didebungakan (46 spesies). Oleh itu, lebah ini boleh digunakan sebagai penunjuk biologi untuk kajian pada masa hadapan.*

Kata kunci: Hutan bermusim; kepelbagaian biologi; lebah asli; Thailand; tumbuh-tumbuhan

INTRODUCTION

Habitat destruction is 4 of the main threats to biodiversity (Ney-Nifle & Mangel 2000). In Thailand, during the severe degradation of forests over the past 5 decades, most of the forest area has been experienced for timber exploitation, agricultural purposes and urbanization. Thus, many protected areas have been designated in order to protect Thailand's biodiversity since 1962. The national parks in lower northern Thailand are mountainous and covered with many different types of forests e.g. deciduous forest (DF), deciduous dipterocarp forest (DDF), seasonal evergreen forest (SEF), evergreen forest (EF), dipterocarp - pine forest (DPF) and mixed evergreen-deciduous forest (MEDF) (Maxwell 2004). The DF, DDF, SEF and DPF are the main vegetation ecosystems found in this area. Thung Salaeng Luang National Park, established in 1963 as Thailand's 3rd national park and the 3rd largest of them, is also 1 of the most abundant forests (DNP 2010). This national park was chosen as study areas to represent 4 dominant forest types (DF, DDF, SEF and DPF) from the lower northern Thailand. The national park is situated between latitudes 16° 25' - 16° 57' N and longitudes 100° 37' – 101° 00' E. The park has an area of 1262.55 sq km and an elevation of approximately 700-860 m above sea level, covering Phitsanulok and Phetchabun provinces in lower northern Thailand (DNP 2010; Nakwa et al. 2008). The previous studies of biodiversity have reported that many species of plants and mushrooms have been recorded and still found in the park (Kaewkrom et al. 2007; Mytnik-Ejsmont & Baranow 2010; Prajaksood et al. 2012). Furthermore,

many new species of insects have also been found in this national park (Hippa 2011; Pauly 2012; Tian et al. 2012). The national park has several different kinds of forest types which can support more species of bees than single facies (Holzschuh et al. 2007; Hoover & Parker 1991).

Bees are the major insect pollinators in Thailand's forests (Jongjitvimol & Wattanachaiyingcharoen 2006; Warrit 2007) and economic crops in Thailand (Boonithee et al. 1991). Native bee pollinators consist of honey bees, stingless bees and bumble bees (Michener 2007). Several studies have reported that the pollen grains were collected by several bees in Thailand (Boongird & Michener 2010; Burgett et al. 2005; Tangmitcharoen et al. 2006). However, there is a lack of information on bee pollinators and pollen sources in the forest of lower northern Thailand. In this study, Thung Salaeng Luang National Park was chosen as the study area for investigating pollen sources of the native bee pollinators (Hymenoptera: Apidae) and the important to their species diversity.

The results can furnish beneficial knowledge on species assemblage of native hymenopterans as pollinators and their food plants in 4 different dominant forest types from the lower northern Thailand. This knowledge will be useful for further biological studies such as systematic studies and sustainable conservation of native bee pollinators in Thailand and other parts of this region.

Materials and Methods

RESEARCH SITE

This research was done in Thung Salaeng Luang National Park, Phitsanulok and Phetchabun provinces from January 2011 to December 2012. A study trail in each forest type, made by experienced park staffs, was used for surveys and sample collection. The detailed descriptions of 4 trails are given below: The DF site is located at Kaeng Sopha Waterfall (elevation 400 m, 16° 53' 16" N and 100° 49' 44" E). The DDF site is located at Nong Mae Na (elevation 700 m, 16° 36' 24" N and 100° 53' 39" E). The SEF site is located at the national park office, Huai Hia (elevation 700 m, 16° 51' 4" N and 100° 52' 45" E). The DPF site is located at Yang Thon (elevation 900 m, 16° 47' 25" N and 100° 59' 4" E). The sampling areas in each forest type were 500 m long and 2 m wide on either side of the trail (2000 sq m).

SAMPLE COLLECTION

Native bee pollinators and pollen samples were collected from each forest type between 09.00 am and 04.00 pm at least once a month, depending on flowering phenology during 2011 to 2012. The sampling areas in each forest type were studies by random sampling and line transects (Krebs 1999). The sampling techniques were sweep net sampling for bees and hand collection for pollens and flowering plants. The honey bait traps were also used to support the purpose for documenting bee species. Plastic Petri dishes (8.5 cm diameter) containing 20 mL of 50% (v/v) honey solution was used to attract bees. The baits were placed for 30 min on the ground of every 20 m along the trail to attract bees. Pollen and bee samples were preserved in 70% (v/v) ethanol. Tree and plant specimens were collected for identification. Field notes included location, habitat and other details were recorded.

SAMPLE IDENTIFICATION

The insect samples of each species were divided into 2 groups. The first group was preserved as dried specimens and used for further identification (Hatch 1926). The second group was kept in 70% ethanol solution at Pibulsongkram Rajabhat University (PSRU), Phitsanulok. The specimens were identified using keys from Michener (2007), Michener and Boongird (2004), Sakagami et al. (1990), Schwarz (1939) and Yamane et al. (1999). Most specimens were confirmed by comparing with the insects deposited in the Naresuan University (NU) museum, Phitsanulok. All voucher specimens of insects were collected and deposited in the Entomology Laboratory, PSRU.

Pollen was taken from pollen baskets of forager bees and flower buds. All samples were prepared by the standard acetolysis method (Erdtman 1960). A pollen key for the local flowering plants was constructed by using pollen grains collected from flower bud and a photograph from a scanning electron microscope (SEM, Leo 1455VP) at NU. Pollen preparation for SEM, acetolysed pollen grains in 70% ethanol solution were mounted on aluminum stubs with double-sided cellophane tape, then air-dried at room temperature. All specimens were coated with gold before SEM study. Having developed the pollen key of this national park, we identified the species of pollen carried by returning forager bees. This pollen was mounted in glycerin jelly for light microscopic (LM) observation. Pollen measurements and morphological observations were analyzed by an Olympus BX-41 microscope at PSRU. Flower visited by native bee pollinators and other plant species were identified at Kasetsart University (KU), Kam Phaeng Saen Campus (KPS), Nakhon Pathom. Finally, the specimen identification was confirmed by comparing them with specimens in Bangkok Herbarium (BK), Forest Herbarium (BKF) and Chulalongkorn University Herbarium (BCU). All voucher herbarium specimens and pollens were deposited in the Botany Laboratory at KU (KPS).

DATA ANALYSES

A list of bee and vascular plant species was made for each forest type. Species composition and species structure indices are calculated to indicate the bee species structure in each forest type. Shannon-Wiener index, *H'* indicates the bee diversity living in the forest which based on the number of bee species within a site and the relative abundance of each bee species (Magurran 1988). Pielou's index, *J'* or the species evenness was used for determining the relative abundance or individual distribution among the different communities (Ludwig & Reynolds 1988). Simpson's

index, *D* or species richness was used for determining the dominant species in each area (Simpson 1949). Sorensen's similarity coefficient, S_s, the similarity index was used for comparing which species are shared between 2 communities (Sorensen 1948). A rarefaction model was also used to compare insect diversity among these forest types. The rarefaction value of 95% confidence interval was computed by EcoSim version 7.72 software (Gotelli & Entsminger 2004). Subsequently, the values of all forest types were plotted as a function of sampling effort. With this plot, significant difference in species diversity was indicated by an absence of overlap in the confidence interval of rarefaction curves among 4 different forest types at maximum sampling effort (Colwell et al. 2004).

Results

A total of 22 species with 4,464 individuals of bee pollinators (Apidae) were recorded in 4 forest types. These were classified into 12 genera in 4 subfamilies: Anthophorinae (4 species), Xylocopinae (5 species), Apinae (4 species) and Meliponinae (12 species) (Table 1). The total numbers of hymenopteran species in each forest type from highest to lowest were 20 species in DF, 17 species in DDF, 15 species in SEF and 11 species in DPF, respectively. All voucher specimens were deposited at the Entomology Laboratory, PSRU.

The species diversity (Shannon-Wiener index), the species evenness (Pielou's indices) and the dominance index (Simpson's index) of all 4 forest types were relatively high (Table 2). DF showed the highest number of species diversity (H' = 2.790), whereas the lowest number was found in the DPF (H' = 2.158). These data were supported by the number of bee species in each forest type. The Pielou's index was highest in DDF (J' = 0.954) and lowest in DPF (J' = 0.900). The dominance index correlated with the Shannon-Wiener index. DF had the highest value (D = 0.933) while the DPF had the lowest value (D = 0.873). The detail of species structure index from the 4 forest types is shown in Table 2.

The Sorensen's similarity coefficient compared among the 4 forest types indicated that different forest habitats influenced bee's species structure. Most similarity measurements were higher than 0.5, except between SEF and DPF (S_s = 0.462) and the most similar habitats were DF and DDF (0.865) (Table 3). The species accumulation

TABLE 1. List and distribution of native bee found in the 4 forest types

Subfamily	Insect species	Forest type			
		DF	DDF	SEF	DPF
1. Anthophorinae	1. *Amegilla florea* (Smith, 1879)	/	/	/	
2. Xylocopinae	2. *Ceratina lieftincki* van der Vecht, 1952	/	/	/	
	3. *Pithilis smaragdula* (Fabricius, 1787)	/	/		/
	4. *Thyreus* sp.	/			/
	5. *Xylocopa confusa* Pérez, 1901	/	/		/
	6. *X. latipes* (Drury, 1773)	/	/		/
3. Apinae	7. *Apis andreniformis* Smith, 1858	/	/	/	
	8. *A. cerana* Fabricius, 1793	/	/	/	/
	9. *A. dorsata* Fabricius, 1793	/	/	/	/
	10. *A. florea* Fabricius, 1787	/	/	/	/
4. Meliponinae	11. *Homotrigona fimbriata* (Smith, 1857)	/	/	/	
	12. *Lepidotrigona nitidiventris* (Smith, 1857)	/	/		
	13. *L. terminata* (Smith,1878)	/		/	
	14. *L. ventralis* (Smith, 1857)	/	/		
	15. *Lisotrigona cacciae* (Nurse, 1907)	/		/	
	16. *Tetragonilla collina* (Smith, 1857)	/	/	/	/
	17. *Tetragonula fuscobalteata* (Cameron, 1908)	/	/	/	
	18. *T. laeviceps* (Smith, 1857)	/	/		/
	19. *T. minor* (Sakagami, 1978)	/		/	
	20. *Tetrigona apicalis* (Smith, 1857)	/	/	/	
	21. *T. melanoleuca* (Cockerell, 1929)		/	/	/
	22. *T. peninsularis* (Cockerell, 1927)			/	/
Total		20	17	15	11

TABLE 2. Ecological indices of native bees in the 4 forest types

Forest type	Ecological index		
	Shannon-Wiener index (*H'*)	Pielou's index (*J'*)	Simpson's index (*D*)
DF	2.790	0.931	0.933
DDF	2.583	0.954	0.920
SEF	2.652	0.936	0.923
DPF	2.158	0.900	0.873

curves (both observed and expected) of all forest types were consistent when the survey stopped (Figure 1).

Pollens collected by all native bees were 62 species in 28 families (Table 4). Several plant species (14 species) were non-native plant species of Thailand and many occurred in disturbed areas. The family Fabaceae (Leguminosae) was the largest number (9 species). The main food source of bees was *Hopea odorata* (Dipterocarpeceae), which was found in both DF and SEF and *Thunbergia laurifolia* were the second most common pollen species collected by native bees (Figure 2).

The dwarf honey bee, *Apis florea,* carried pollen of 46 plant species - the highest number of all species. The stingless bee, *Tetragonula fuscobalteata*, was the second highest pollen carrier with 44 plant species found. The stingless bee, *Tetragonilla collina* was the third highest pollen carrier with collection of 37 plant species. Mostly, bees collected pollen from *Hopea odorata* (19 bee species, 86.36%) and *Thunbergia laurifolia* (18 bee species, 81.82%) whereas the pollen of *Croton poilanei*, *Suregada multiflora* and *Mimosa pudica* were collected by 15 bee species (68.18%). Some plant species were found in all forest types e.g. *Ageratum conyzoides*, *Chromolaena odorata* and *Clerodendrum infortunatum*, but these species were not popular for bees. Moreover, pollen of 11 plant species e.g. *Oxyceros horridus* and *Pavetta indica* were rarely collected by a few bee species (Table 5).

DISCUSSIONS AND CONCLUSION

Apidae is the most important family of hymenopteran pollinators in Thailand. These bees are considered as the most important pollinators for many introduced and indigenous plants in Thailand e.g. teak trees (*Tectona grandis*) (Tangmitcharoen et al. 2009) and physic nuts (*Jatropha curcas)* (Inson & Malaipan 2011). Of all the 62 plant species, *Apis florea* collected the highest number of pollen species (46 species). It is probable that this bee has a small body size and widespread across mainland Asia with the elevations range from sea level to approximately 2000 m (Hepburn & Radloft 2011). Thus, this bee has successfully occupied in all types of habitat

TABLE 3. The Sorensen's similarity coefficient (S_s) of insect species in the 4 forest types

Forest type	DF	DDF	SEF	DPF
DF	---	0.865	0.743	0.581
DDF	16	---	0.688	0.643
SEF	13	11	---	0.462
DPF	9	9	6	---

Numbers in the upper right half of the table are the indices of similarity shared between 2 sites, and numbers in the lower left half are the number of species found in both sites

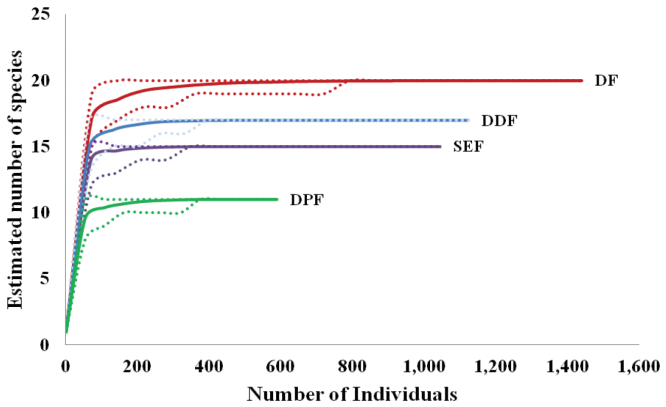

FIGURE 1. Species accumulation curve for bees in the 4 forest types with ±95% confidence interval as presented as dotted lines

TABLE 4. List and distribution of plant found in the 4 forest types

Family	Plant species	Forest type			
		DF	DDF	SEF	DPF
1. Acanthaceae	1. *Barleria strigosa* Willd.	/			
	2. *Thunbergia laurifolia* Lindl.	/			/
2. Agavaceae	3. *Dracaena fragrans* (L.) Ker - Gawl.*			/	
3. Amarylidaceae	4. *Crinum asiaticum* L.*	/			
	5. *Hippeastrum harrisonii* (Lindl.) Hook.f.*			/	/
4. Anacardiaceae	6. *Dracontomelon dao* (Blanco) Merr. & Rolfe			/	
5. Asparagaceae	7. *Dracaena angustifolia* (Medik.) Roxb.			/	
	8. *Peliosanthes teta* Andrews subsp. *humilis* (Andrews) Jessop ex Gandhi			/	
6. Asteraceae	9. *Acmella oleracea* (L.) R.K.Jansen*		/	/	/
(Compositae)	10. *Ageratum conyzoides* (L.) L.*	/	/	/	/
	11. *Blumea balsamifera* (L.) DC.				/
	12. *Blumea* sp.		/	/	
	13. *Chromolaena odorata* (L.) R.M.King & H.Rob.*	/	/	/	/
	14. *Conyza sumatrensis* (S.F.Blake) Pruski & G.Sancho			/	/
	15. *Cosmos sulphureus* Cav.*	/	/	/	/
7. Cardiopteridaceae	16. *Gonocaryum lobbianum* (Miers) Kurz			/	/
8. Clusiaceae	17. *Calphyllum inophyllum* L.			/	
9. Convolvulaceae	18. *Argyreia capitiformis* (Poir.) Ooststr.	/			
	19. *Argyreia* sp.	/			
10. Costaceae	20. *Cheilocostus speciosus* (J.König) C.Specht	/			
11. Dipterocarpaceae	21. *Hopea odorata* Roxb.	/		/	
12. Euphorbiaceae	22. *Antidesma* sp.			/	
	23. *Croton poilanei* Gagnep.	/			
	24. *Homonoia riparia* Lour.			/	
	25. *Mallotus barbatus* Müll.Arg.				/
	26. *Phyllanthus pulcher* (Baill.) Wall. ex Müll.Arg.	/			/
	27. *Suregada multiflora* (A.Juss.) Baill.	/		/	
13. Lamiaceae	28. *Clerodendrum villosum* Blume			/	/
	29. *Clerodendrum infortunatum* L.	/	/	/	/
	30. *Gmelina arborea* Roxb.	/			
14. Lecythidaceae	31. *Careya arborea* Roxb.	/			
15. Lythraceae	32. *Lagerstroemia speciosa* (L.) Pers.		/	/	
	33. *Lagerstroemia tomentosa* C.Presl		/	/	
16. Fabaceae	34. *Afzelia xylocarpa* (Kurz) Craib.	/			
(Leguminosae)	35. *Caesalpinia sappan* L.				/
	36. *Caesalpinia pulcherrima* (L.) Sw.*	/			
	37. *Cassia fistula* L.	/			
	38. *Erythrina variegata* L.*			/	
	39. *Mimosa pudica* L.*	/	/	/	/
	40. *Phyllocarpus septentrionalis* Donn. Sm.*	/			
	41. *Pterocarpus indicus* Willd.	/			
	42. *Pterocarpus macrocarpus* Kurz	/			
17. Malvaceae	43. *Sterculia lanceolata* Cav. var. *coccinea* (Jack) Phengklai			/	
	44. *Urena lobata* L.	/	/		/
18. Marantaceae	45. *Donax canniformis* (G.Forst.) K.Schum.			/	
19. Melastomataceae	46. *Melastoma malabathricum* L.		/		/
20. Orchidaceae	47. *Cymbidium aloifolium* (L.) Sw.			/	
21. Polygonoceae	48. *Persicaria chinensis* (L.) H.Gross			/	
22. Proteaceae	49. *Macadamia ternifolia* F.Muell.*			/	
23. Rubiaceae	50. *Chassalia curviflora* (Wall.) Thwaites	/		/	
	51. *Duperrea pavettifolia* (Kurz) Pit. var. *scabra* (Craib) Pit.			/	
	52. *Morinda angustifolia* Roxb.			/	
	53. *Oxyceros horridus* Lour.			/	
	54. *Pavetta indica* L.			/	
	55. *Prismatomeris sessiliflora* Pierre ex Pit.			/	
24. Rutaceae	56. *Clausena excavata* Burm.f.	/			
	57. *Micromelum minutum* (J.G. Forster) Wight & Arn.			/	
25. Sapindaceae	58. *Dimocarpus fumatus* (Blume) Leenh.			/	
	59. *Lepisanthes rubiginosa* (Roxb.) Leenh.	/		/	/
26. Solanaceae	60. *Solanum torvum* Sw.*				/
27. Verbenaceae	61. *Lantana camara* L.*				/
28. Zingiberaceae	62. *Alpinia* sp.	/			/
	Total	28	11	**37**	21

note: *non-native plant species of Thailand

TABLE 5. Pollen sources of 22 bee species

Plant species	Insect species																							Total
	A. florae	*C. lieftincki*	*P. smaragdula*	*Thyreus* sp.	*X. confusa*	*X. latipes*	*A. andreniformis*	*A. cerana*	*A. dorsata*	*A. florea*	*H. fimbriata*	*L. nitidiventris*	*L. terminata*	*L. ventralis*	*L. cacciae*	*T. collina*	*T. fuscobalteata*	*T. laeviceps*	*T. minor*	*T. apicalis*	*T. melanoleuca*	*T. peninsularis*		
1. *Barleria strigosa*	/						/			/					/		/							5
2. *Thunbergia laurifolia*	/	/				/	/		/		/	/	/	/	/	/	/	/	/	/	/	/	/	18
3. *Dracaena fragrans*							/	/	/	/	/			/		/	/			/				9
4. *Crinum asiaticum*		/								/							/	/						4
5. *Hippeastrum harrisonii*		/								/						/	/	/						5
6. *Dracontomelon dao*		/					/	/		/							/		/					6
7. *Dracaena angustifolia*		/								/			/				/							4
8. *Peliosanthes teta*	/	/						/	/								/		/					6
9. *Acmella oleracea*		/										/	/				/		/					5
10. *Ageratum conyzoides*		/	/					/		/						/								5
11. *Blumea balsamifera*										/						/		/			/			4
12. *Blumea* sp.										/							/	/	/					4
13. *Chromolaena odorata*		/						/		/						/	/							5
14. *Conyza sumatrensis*			/													/	/	/						4
15. *Cosmos sulphureus*	/	/		/				/	/	/					/	/	/	/		/	/			12
16. *Gonocaryum lobbianum*		/								/		/					/	/						5
17. *Calphyllum inophyllum*	/							/	/		/									/	/			6
18. *Argyreia capitiformis*				/	/	/	/	/		/	/	/	/	/						/				11
19. *Argyreia* sp.			/	/	/	/	/	/		/	/		/	/	/					/				12
20. *Cheilocostus speciosus*	/				/	/		/	/								/	/						7
21. *Hopea odorata*	/	/		/	/	/	/	/	/	/		/	/	/		/	/	/	/	/	/	/		19
22. *Antidesma* sp.		/															/		/					3
23. *Croton poilanei*		/			/		/	/	/	/	/	/	/	/		/	/	/	/	/				15
24. *Homonoia riparia*		/					/			/										/	/			5
25. *Mallotus barbatus*			/	/	/			/	/	/						/		/			/	/		10
26. *Phyllanthus pulcher*		/					/			/							/	/			/			6
27. *Suregada multiflora*	/	/			/	/		/		/	/	/		/	/	/	/	/		/		/		15
28. *Clerodendrum infortunatum*		/						/		/						/	/			/				6
29. *Clerodendrum villosum*		/						/		/							/	/						5
30. *Gmelina arborea*	/				/	/		/	/	/	/	/	/			/	/			/				12
31. *Careya arborea*										/			/			/	/							4
32. *Lagerstroemia speciosa*	/		/		/	/		/	/	/	/					/	/					/		11
33. *Lagerstroemia tomentosa*	/		/		/	/		/	/	/	/					/	/					/		11
34. *Afzelia xylocarpa*					/	/					/					/				/				5
35. *Caesalpinia sappan*										/						/					/			3
36. *Caesalpinia pulcherrima*	/	/						/		/						/	/	/						7
37. *Cassia fistula*	/				/	/		/		/						/		/		/				8
38. *Erythrina variegata*		/					/	/	/	/							/							6
39. *Mimosa pudica*		/					/	/	/	/	/	/	/	/		/	/	/	/	/	/			15
40. *Phyllocarpus septentrionalis*					/	/			/	/	/					/	/			/				8
41. *Pterocarpus indicus*					/	/		/	/	/						/	/			/				8
42. *Pterocarpus macrocarpus*		/			/	/		/	/	/						/	/			/				9
43. *Sterculia lanceolata*		/						/		/						/								4
44. *Urena lobata*	/		/		/	/		/	/	/						/	/			/	/			11
45. *Donax canniformis*	/		/		/	/											/	/						6
46. *Melastoma malabathricum*								/	/	/						/	/			/				6
47. *Cymbidium aloifolium*	/																		/					2
48. *Persicaria chinensis*		/															/		/					3
49. *Macadamia ternifolia*	/	/						/	/	/	/					/				/	/			9
50. *Chassalia curviflora*																	/	/	/					3
51. *Duperrea pavettifolia*																	/		/					2
52. *Morinda angustifolia*																/	/		/					3
53. *Oxyceros horridus*																	/		/					2
54. *Pavetta indica*																	/		/					2
55. *Prismatomeris sessiliflora*																/	/							2
56. *Clausena excavata*		/								/						/	/	/						5
57. *Micromelum minutum*		/						/		/						/								4
58. *Dimocarpus fumatus*								/	/	/						/	/		/					6
59. *Lepisanthes rubiginosa*		/								/								/						3
60. *Solanum torvum*								/		/						/					/			4
61. *Lantana camara*				/						/						/		/						4
62. *Alpinia* sp.	/				/	/				/						/								5
Total	18	29	8	6	19	17	11	33	20	46	14	9	11	7	5	37	44	23	17	27	13	6		

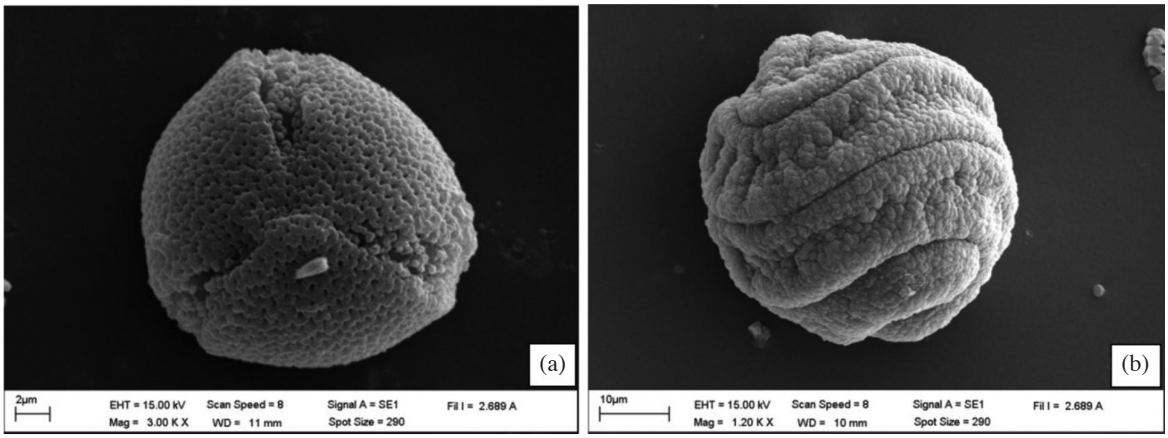

FIGURE 2. Two most common pollen found, (a): *Hopea odorata* Roxb. and (b): *Thunbergia laurifolia* Lindl. collected by 22 bee species

and was more plentiful than other native bees. The most attractive plant as a pollen source by 19 native bees was *Hopea odorata*, which was found in DF and SEF (Table 5). It might be possible that this plant species was more general and was more attractive to a variety of insect pollinators. In contrast, some plants were specific to bee species that was visited by only few species of bee pollinators. For example, *Oxyceros horridus* and *Pavetta indica* were pollinated by 2 species of stingless bees (*Tetragonula fuscobalteata* and *Tetragonula minor*). Farkas and Orosz-Kovács (2004) explained that insect pollinators are attracted to flowers by their shape, size, and color. In addition, not only *Apis florea* was most commonly found but *Tetragonula fuscobalteata* and *Tetragonilla collina* were also involved with many plant species which were found in all forest types. Herein, 3 native bees are considered as most important of insect pollinators (Inson & Malaipan 2011; Jongjitvimol & Wattanachaiyingcharoen 2006).

All plant species found in each forest type were clearly different (Table 4). Thus, there were different in species richness, abundance, diversity or evenness among the 4 forest types (Tables 1 and 2). Generally the higher number of plant species will lead to more biodiversity of pollinators (Blüthgen & Klein 2011; Fontaine et al. 2006). In this study, the number of bee species (Table 1) was not related with the number of plant species (Table 4). Although in the DF we recorded the lower number of plant species (28 species) than in the SEF (37 species), in the DF showed higher number of bee species (20 species) while in the SEF only 15 species of bees were observed. From these different results, it is plausible that bee species diversity could be affected by some physical factor, for instance, forest disturbance, forest fire or dryness (Kambach et al. 2013). Thus, relationship between insect pollinators and seasonal change of physical factors in light intensities, temperatures and precipitations should be involved for further studies.

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REFERENCES

Blüthgen, N. & Klein, A.M. 2011. Functional complementarity and specialisation: Why biodiversity is important in plant-pollinator interactions. *Basic and Applied Ecology* 12(4): 282-291.

Boongird, S. & Michener, C.D. 2010. Pollen and propolis collecting by male stingless bees (Hymenoptera: Apidae). *Journal of the Kansas Entomology Society* 83(1): 47-50.

Boonithee, A., Juntawong, N., Pechhacker, H. & Hüttinger, E. 1991. Floral visits to selected crops by 4 *Apis species* and *Trigona* sp. in Thailand. *Acta Horticulturae* 288: 74-80.

Burgett, M., Sukumalanand, P. & Vorwohl, G. 2005. Pollen species resources for *Xylocopa* (*Nyctomelitta*) *tranquebarica* (F.) a night-flying carpenter bee (Hymenoptera: Apidae) of Southeast Asia. *ScienceAsia* 31(1): 65-68.

Colwell, R.K., Mao, C.X. & Chang, J. 2004. Interpolating, extrapolating, and comparing incidence-based species accumulation curves. *Ecology* 85(10): 2717-2727.

DNP (Department of National Parks, Wildlife and Plant Conservation). 2010. *National Parks in Thailand*. 2nd ed. Bangkok: Department of National Parks, Wildlife and Plant Conservation.

Erdtman, G. 1960. The acetolysis method, a revised description. *Svensk Botanisk Tidskrift* 54(4): 561-564.

Farkas, A. & Orosz-Kovács, Z.S. 2004. Primary and secondary attractants of flowers in pear *Pyrus betulifolia*. *Acta Horticulturae* 636(1): 317-324.

Fontaine, C., Dajoz, I., Meriguet, J. & Loreau, M. 2006. Functional diversity of plant-pollinator interaction webs enhances the persistence of plant communities. *Plos Biology* 4(1): 129-135.

Gotelli, N.J. & Entsminger, G.L. 2004. *EcoSim: Null Models Software for Ecology V. 7*. Acquired Intelligence Inc. & Kesey-Bear. Jericho, VT. http://garyentsminger. com/ecosim/index.htm. Accessed October 10, 2013.

Hatch, M. 1926. Concerning the insect collection. *Entomological News* 37(12): 329-332.

Hepburn, H.R. & Radloft, S.R. 2011. Biogeography. In *Honey bee of Asia,* edited by Hepburn, H.R. & Radloft, S.R. New York: Heidelberg Dordrecht London. pp. 51-67.

Hippa, H. 2011. New species and new records of *Manota* Williston (Diptera, Mycetophilidae) from Thailand, with a key to the Oriental and Palaearctic species. *Zootaxa* 2763: 39-60.

Holzschuh, A., Steffan-Dewenter, I., Kleijn, D. & Tscharntke, T. 2007. Diversity of flower-visiting bees in cereal fields: Effects of farming system, landscape composition and regional context. *Journal of Applied Ecology* 44(1): 41-49.

Hoover, S.R. & Parker, A.J. 1991. Spatial components of biotic diversity in landscapes of Georgia, USA. *Landscape Ecology* 5(3): 125-136.

Inson, C. & Malaipan, S. 2011. Diversity of bee (Hymenoptera: Apoidea) as insect pollinators on physic nuts (Euphorbiaceae: *Jatropha curcas* L.). *Thai Journal of Agricultural Science* 44(4): 263-269.

Jongjitvimol, T. & Wattanachaiyingcharoen, W. 2006. Pollen food sources of the stingless bees *Trigona apicalis* Smith, 1857, *T. collina* Smith, 1857 and *T. fimbriata* Smith, 1857 (Apidae, Meliponinae) in Thailand. *Natural History Journal of Chulalongkorn University* 6(2): 75-82.

Kaewkrom, P., Thummikkaphong, S. & Somnoumtad, T. 2007. Population ecology of some important palm species in Phetchabun province. *Kasetsart Journal (Natural Science)* 41(4): 407-513.

Kambach, S., Guerra, F., Beck, S.G., Hensen, I. & Schleuning, M. 2013. Human-induced disturbance alters pollinator communities in tropical mountain forests. *Diversity* 5(1): 1-14.

Krebs, C.J. 1999. *Ecology Methodology*. 2nd ed. New York: A Wesley Longman.

Ludwig, J.A. & Reynolds, J.F. 1988. *Statistical Ecology*. New York: John Wiley and Sons.

Magurran, A.E. 1988. *Ecological Diversity and Its Measurement*. New Jersey: Princeton University Press.

Maxwell, J.F. 2004. A synopsis of the vegetation of Thailand. *Natural History Journal of Chulalongkorn University* 4(2): 19-29.

Michener, C.D. & Boongird, S. 2004. A new species of *Trigona* from Peninsular Thailand (Hymenoptera: Apidae: Meliponini). *Journal of the Kansas Entomological Society* 77(2): 143-146.

Michener, C.D. 2007. *The Bees of the World*. 2nd ed. USA: John Hopkins University Press.

Mytnik-Ejsmont, J. & Baranow, P. 2010. Taxonomic studies of *Polystachya* Hook. (Orchidaceae) from Asia. *Plant Systematics and Evolution* 290: 57-63.

Nakwa, A., Sitasuwan, N., Jatisatein, A., Chantaramongko, P., Pupichit, W. & Srisak, P. 2008. The effects of tourists on bird diversity in tourist area compared to restricted area of seasonal evergreen forest at Tung Salang Luang National Park, Phetchabun province, Thailand. *International Journal of Zoology Research* 4(2): 96-105.

Ney-Nifle, M. & Mangel, M. 2000. Habitat loss and changes in the species-area relationship. *Conservation Biology* 14(3): 893-898.

Pauly, A. 2012. Three new species of *Eupetersia* Blüthgen, 1928 (Hymenoptera, Halictidae) from the Oriental Region. *European Journal of Taxonomy* 14: 1-12.

Prajaksood, A., Parnell, J.A.N. & Chantaranothai, P. 2012. New taxa and new combinations of Eriocaulaceae from Thailand. *Kew Bulletin* 67: 1-31.

Sakagami, S.F., Inoue, T. & Salmah, S. 1990. Stingless bees of central Sumatra. In *Natural History of Social Wasps and Bees in Equatorial Sumatra*, edited by Ohgushi, R., Sakagami, R.F. & Roubik, D.W. Sapporo: Hokkaido University Press. pp. 125-137.

Schwarz, H.F. 1939. The Indo-Malaysan species of *Trigona*. *Bulletin of the American Museum of Natural History* 76(3): 83-141.

Simpson, E.H. 1949. Measurement of diversity. *Nature* 163: 688.

Sorensen, T.A. 1948. A method of establishing groups of equal amplitude in plant sociology based on similarity of species content, and its application to analyses of the vegetation on Danish commons. *Kongelige Danske Videnskabernes Selskab, Biologiske Skrifter* 5(4): 1-34.

Tangmitcharoen, S., Takaso, T., Siripatanadilox, S., Tasen, W. & Owens, J.N. 2006. Behavior of major insect pollinators of teak (*Tectona grandis* L.f.): A comparison of clonal seed orchard versus wild trees. *Forest Ecology and Management* 222: 67-74.

Tangmitcharoen, S., Tasen, T., Owens, J.N. & Bhodthipuks, J. 2009. Fruit set as affected by pollinators of teak (*Tectona grandis* L.f.) at two tree spacings in a seed orchard. *Songklanakarin Journal of Science and Technology* 31(3): 255-259.

Tian, M., Deuve, T. & Felix, R. 2012. Orthogonius species and diversity in Thailand (Coleoptera, Caraboidea, Orthogoniini), a result from the TIGER project. *ZooKeys* 164: 51-90.

Warrit, N. 2007. *Ceratina* (*Ceratinidia*) *compacta*, a small carpenter bee in Thailand: An apparent recent addition to the fauna (Hymenoptera: Apidae). *Journal of the Kansas Entomology Society* 80(1): 72-77.

Yamane, S.k., Ikudome, S. & Terayama, M. 1999. *Identification Guide to the Aculeata of the Nansei Islands, Japan*. Sapporo: Hokkaido University Press.

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