# Conservation and sustainable utilization of stingless bees for pollination services in agricultural ecosystems in Malaysia

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## Abstract

Pollination is a critical for food production and human livelihoods. Currently, honey bees are major pollination service provider to many agricultural crops. However, there is clear evidence of recent declines in honey bees and it is urgent need to look for alternative and native pollinators.

Malaysia is rich with native pollinator such as stingless bees. Currently, at least thirty-two species were inventoried and four species could be used to pollinate several agricultural crops such as starfruit, guava, citrus, mango, watermelon, durian, and coconut. The value of insect pollination service of these crops was estimated more than USD 19 million.

Several issues to be considered before stingless bees can be utilized as pollination service provider in agricultural ecosystem. These issues included conservation of their species, capacity building and research on their biology, ecology and behavior. Preliminary works at MARDI suggests that at least eleven species of stingless bees were potentially domesticated. Out of these, four species - *Trigona itma, T. thoracica, T. atripes and T. peninsularis,* were able to be utilized to pollinate several agricultural crops.

**Keywords:** stingless bee, diversity, pollination service, conservation, agricultural ecosystem,

## 1. Introduction

Insect pollinators pollinate about 80% of flowering plants (FA0, 2007). Many plants have evolved intricate relationships with many insect pollinators, without which they would not reproduce and/or maintain their genetic diversity (Daily et al., 1997). In natural ecosystem, insect pollinate more than 50% of tropical forest and thus they play a major role in maintaining and conserving biodiversity. In agricultural ecosystem, many agricultural crops are dependent on insects for their pollination, and assisted pollination may have to be done when natural pollination is insufficient in order to reduce potential yield loss (Klein et al., 2007).

On a global scale, the total annual value of insect pollination services has been estimated at USD 217 billion (Sciencedaily, 2008). In Malaysia, only a case study of quantifying the pollination service by a weevil, *Elaeidobius kamerunicus* in oil palm plantation is documented. The weevil introduced into oil palm plantation into this country in 1981, has been proven not only to successfully improve pollination and increase fruit set of the palm oil but eliminated the costly and inefficient process of assisted pollination (Syed et al., 1982). The pollination service provided by this beetle saved the oil palm industry USD 100 million per year.

Bees are the most important insect pollinator because a wide variety of them are known to be efficient and effective pollinators of many plant species (FA0, 2007). However, numbers of them especially honey bee are declining rapidly, causing global concern for pollination services (Kearns et al., 1998; Biesmeijer et al., 2006). Loss of bees could seriously threaten food security and biodiversity (FA0, 2007). Convention of Biological Diversity established an International Initiative for the Conservation and Sustainable use of Pollinators in 2000. The initiative aims to promote sustainable use of pollinator diversity in agriculture and related ecosystems.

Conservation of bee diversity would help to achieve pollination services in case commonly used honey bee is diminishing. This conservation effort helps to avoid introduction of exotic pollinators as it may bring the disease and parasite with them. Malaysia is proud to be blessed with an extremely rich natural resources and biodiversity. Malaysia hosts wide variety stingless bees (Momose et al., 1998).

## 2. Stingless bees in Malaysia

Stingless bees are a large group of bees in the family Apidae, and closely related to the common honey bees. There are about 700 species have been recorded worldwide and they are mostly found in tropical countries (Heard, 1999). They are variable in their body size, ranging from 2 to 14 mm. Currently, 32 species of them were inventoried (Schwarz, 1939; Sakagami et al., 1985; Osawa and Tsubaki, 2003) Appendix A. In one of the recent study about a dozen of them commonly found. They were represented by *Trigona itama, T. thoracica, T. apicalis, T. terminata, T. respani, T. melanocephala, T. valdezi, T. collina, T. atripes, T. canifrons, T. iridepennis and T. rufibasalia*.

Stingless bees are active all year round and they do not sting but will defend by biting if their nest is disturbed. They usually nest in hollow trunks, tree branches, underground cavities, or rock crevices but they have also been encountered in wall cavities, old rubbish bins, water meters, and storage drums. Stingless bees are true generalists, collecting nectar and pollen from a vast array of plants (Heithaus, 1979; Biesmeijer et al., 2005). Stingless bees are known to be important pollinator in tropical rainforest (Eltz et al., 2003) and also good candidates for providing pollination services in agricultural ecosystem (Heard, 1999; Slaa et al., 2006). It is in need to study their potential impact especially in agricultural ecosystem since human activities are affecting their services (Samejima et al., 2004).

### 2.1 Potential values of stingless bees pollination service

Even though stingless bees are common pollinators in Malaysian agricultural ecosystem, their contributions to human socio-economic have yet to be quantified or even appreciated. In fact there has yet a complete study had been carried out to use stingless bees to enhance crop or horticultural productions. Studies in Australia, Japan and Mexico showed very promising results (Kukutani et al., 1993; Blanche et al., 2006; Palma et al., 2008). In Japan, (Kukutani et al., 1993) showed that the stingless bees pollinated strawberries as well as honeybees.

Many agricultural crops in Malaysia such as starfruits, mango, durian, watermelon, guava and coconut could be pollinated by stingless bees (Slaa et al., 2006). Table 1 estimated the potential value of pollination service for the above commodities in Malaysia in 2008. The value was more than USD 19 millions. It was estimated by multiply production value of each commodity with its pollinator dependence ratio (Gallai et al., 2009). Table 1 indicated potential value of pollination services for some of agricultural crop in Malaysia. The actual values of pollination service will be higher if the services of pollination for other agricultural crops and forest ecosystems are considered (Samejima et al., 2004). In addition, stingless bees are also producing honey and propolis. Honey of stingless bee is important as honey of common honey bees. Honey is very nutritious to human and propolis is well-known for its medicinal value.

Table 1. Economic impact of pollination services of major Malaysian fruits pollinated by insects[1].

| Commodities | Production Value (USD) | Pollinator Dependence Ratio (USD) | Insect Pollinator Economic values |
|---|---|---|---|
| Starfruits | 5,218,071.08 | 0.65 | 3,391,746.20 |
| Guava | 481,445.14 | 0.65 | 312,939.34 |
| Citrus (Mandrin) | 143,078.11 | 0.05 | 7,153.91 |
| Mango | 911,512.43 | 0.65 | 592,483.08 |
| Watermelon | 9,970,436.22 | 0.95 | 9,471,914.41 |
| Durian | 4,781,793.24 | 0.65 | 3,108,165.61 |
| Coconut | 9,026,651.35 | 0.25 | 2,256,662.84 |
| Total | 30,532,987.57 | | 19,141,065.38 |

## 2.2 Issues and challenges of utilising stingless bees pollination services

Although there are several advantages of stingless bees compare to honey bee for pollination services in agricultural ecosystem, several issues need to be addressed. The first and the most urgent step are to secure as many as possible the number of stingless bees found in Malaysia. This effort only can be done with proper conservation strategies such, protected areas as well as strengthen or formulated any legal framework to protect and sustainable use of stingless bees. At the same time, collection and identification need to be continually conducted.

The second issue is to increase capacity building among the stakeholders. For example, insect taxonomist is scarce in number although they are essential for correct identification of stingless bee species. Botanist, plant ecology and insect ecology are also needed in order to understand stingless bee and plant relationship. Food specialist is very helpful to analyse stingless bee honey and propolis for food and medicinal purpose.

[1] Data on the production value were obtained from Department of Agriculture, Malaysia, 2008.

The third issue is to enhance research and development especially in aspects to increase sustainable utilization of stingless bees in agricultural ecosystem. There is a great need for research in the biology and ecology of stingless bees. For instances, research in the area of domestication and increase number of hives is crucial. At the same time, proper methodology of quantification pollination services of stingless bees is critically needed. All these knowledge will lead better use and conserve of stingless bees. Significant amount of fund is required to conduct this research.

# 3 Current works on sustainable utilization of stingless bees

## 3.1 Formulation of National Strategies for pollinator conservation and sustainable utilization

In recognition the importance of managing agricultural biological diversity such stingless bees, Malaysia formulated National Strategies and Action Plan for Agricultural Biodiversity Conservation and Sustainable Utilization. The strategies are prepared by all stakeholders that relate to agricultural biodiversity. The strategies strive for coordinated and holistic ways to identify, conserve and optimize the use of agricultural biodiversity in the country.

Part of the strategies consisted of various action plans aim to conserve and sustainable use pollinator diversity. They are in line with International Pollinator Initiative of CBD. Those strategies are collecting, documenting and preserving agriculturally important arthropod pollinator. Other strategies include, strengthening the taxonomic studies as it is essential for conservation effort; evaluation ecosystem services to promote sustainable utilization; reduction of pollinator loss in agricultural ecosystem; enhancing awareness and understanding among stakeholders; and the legal and institutional framework to reduce loss of arthropod pollinator diversity.

## 3.2 Conservation of stingless bees

One of MARDI research themes is conservation and sustainable utilization of pollinator diversity, especially stingless bees. Two types of conservations are conducted – inventory and ex-situ conservation. For inventory activities, there are 29 species of local stingless bees were collected and identified (Appendix A).

For ex-situ conservation, a pollinator garden was established in fruits tree area in MARDI Research Station at Serdang. The garden was started in 2007 and presently hosts 11 species stingless bees. These species are *T. itama*, *T. thoracica*, *T. canifrons*, *T. atripes*, *T. fimbriata*, *T. nitidiventris*, *T. peninsularis*, *T. collina*, *T. pagdeniformis*, *T. valdezi* and *T. melanoleuca*. The main objective of the garden is to become referral centre for pollinator of agricultural crops with more emphasis on stingless bees. Besides conservation, the garden will also serves as research centre for stingless bees. Two main research activities are ongoing, gathering information on the behaviour stingless bees and evaluation on the medicinal value of honey and propolis of stingless bees.

Recently, the medicinal value of honey of stingless bees has been analysed. Free-phenolic acids content in the honey were extracted using liquid-liquid separation technique and analysed using gas chromatography mass spectrometry (GC-MS). Our preliminary result indicated that phenylpropanoic acid, protocatechuic acid and 4-hydroxyphenylacetic acid were the major free phenolic acid. In total, more than 300 mg/g dry weight of phenolic acid was found in stingless bee honey and this amount were higher compare to any of the local or imported honey tested. Free phenolic acids are well absorbed by the human body compare to flavonoids.

In addition, the garden will also serve as a training centre for stingless bee keeper in Malaysia, tourist attraction place and a source of public awareness rising centre on the important stingless bees for human well-being.

### 3.3 Survey of pollinator diversity in agricultural ecosystems

Survey on insects visiting important fruits in Malaysia such as mango, starfruit, durian, rambutan, watermelon and honeydew were carried out in 2006 till now. Sweep net was used to collect all arthropods that were found on the open flowers of those fruits. Although all observed insects were collected, more emphasis was given for collecting and identification of stingless bees. The collections were made in early morning to midday. Table 2 indicates list fruit tree and its stingless bee pollinator

Table 2. List of fruit tree and associated stingless bee species

| Fruit trees | Stingless bee species |
|---|---|
| Mango | *T. thoracica, T. apicalis* and *T. atripes* |
| Starfruit | *T. thoracica* |
| Durian | *T. thoracica* |
| Rambutan | *T. thoracica* and *T. atripes* |
| Watermelon | *T. thoracica, T. itama, T. peninsularis* and *T. atripes* |
| Honeydew | *T. thoracica* and *T. itama* |

Detailed study was conducted for monitoring pollinator activities and behavior on mango. As an addition to visual and swept net methods, pollinator activities were monitored with a computer vision system (Mohd Norowi et al., 2008). The system consists of hardware and software components. The hardware components were eight closed circuit television cameras and digital video recording, while the software component was an insect counter. The system can be used to capture high quality video images of pollinator and then stored into the system hard disk. The recorded video can be viewed/play back and image of pollinators can be analysed. New developed MARDI-Picture Viewer software can be used to identify and count the pollinators.

Result of visual and sweep net survey indicated that the order highest number of species were from order Hymenoptera (ants, bees, wasps), Diptera (flies), Heteroptera (bugs) and Lepidoptera (butterflies, moths). Result of computer vision monitoring suggested that stingless bees could be major pollinator of mango as they were observed on peak pollinating time between 9-11am. This is believed to be effective because the mango female flowers are most receptive at this hour. There were three stingless bees observed to visit mango flowers - *T. thoracica, T. apicalis* and *T. atripes.* Figure 1 shows the pollinator, mostly stingless bees and flies temporal pattern activities on mango flower. Data from the computer vision system indicated linear relationship between pollinator counts and number of fruit set.

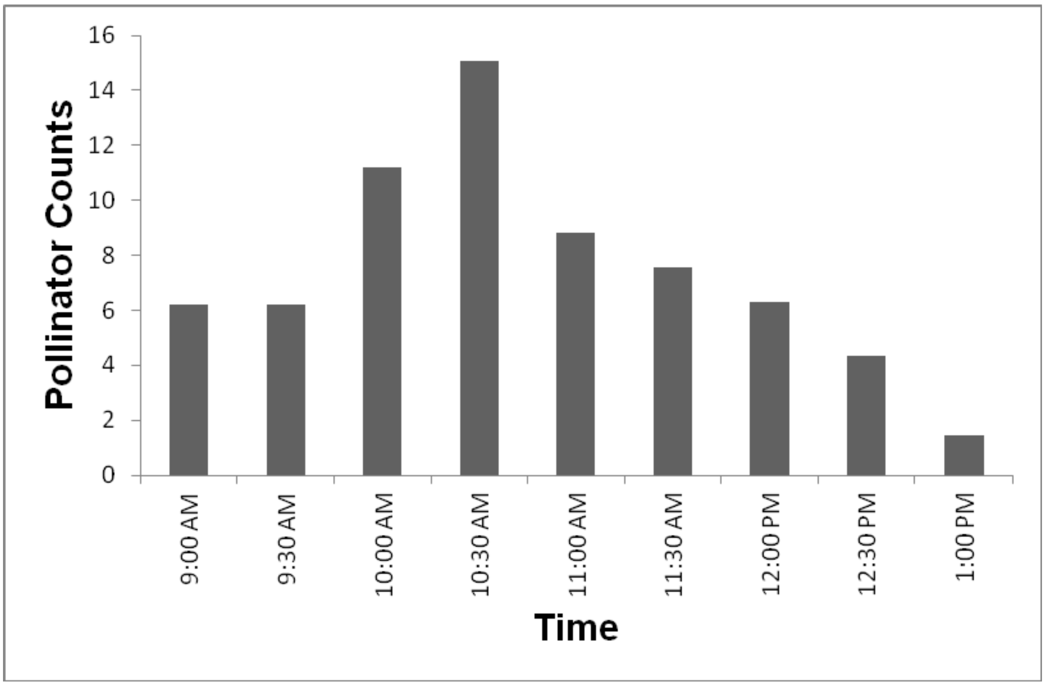


Figure 1. Daily distribution of pollinator counts on mango flowers

### 3.4 Stingless bee diversity in natural and agricultural ecosystems

Stingless bee diversity in natural ecosystem -Templer Park Forest Reserve (TPFR) and in nearby agricultural ecosystem - Selangor Fruit Valley (SFV) were monitored since January to June 2010. Their populations were sampled six times with two kinds of sampling methods – visual and bait. On each sampling date, two sampling points were selected and observation was carried out between 9-11 am for three consecutive days. For visual method, stingless bees that were visiting flowering plant were sampled with sweep net. For bait method, 50% honey solution has been sprayed on vegetation in the vicinity of sampling area (Osawa and Tsubaki, 2003). Any visited stingless was captured with sweep net. They were killed and brought to laboratory for identification and counting.

TPFR and SFV are about 50km apart and were separated by highway and residential areas. On the hand, they may also be connected by various sizes of agricultural areas and semi-natural habitats. SFV was formerly part of forest area that was connected to TPFR. The area of SFV is about 2,000 hectares. It was developed in 2002 and currently planted with various tropical fruits such as starfruit, pineapple, citrus, jackfruit, guava and mango. All these fruits were visited by stingless bees (Heard, 1999; Slaa et al., 2006). The main objective is to examine the movement stingless bees between natural and nearby agricultural ecosystems.

Figure 2 shows the diversity and abundance of stingless bees in TPFR and SFV. Six stingless bee species were sampled in TPFR and only four species were sampled in SFV. *T. itama, T. thoracica, T. atripes and T. peninsularis* were captured in both ecosystems while *T. pagdeniformis and T. canifrons* were only captured in TPFR. All these species already inventoried before. Two species, *T. itama, T. thoracica* were the most abundance in SFV while *T. atripes and T. peninsularis* were only captured in April – June sampling dates. This preliminary result implies that *T. itama, T. thoracica, T. atripes and T. peninsularis* were foraging in natural and agricultural ecosystems while *T. pagdeniformis* and *T. canifrons* were only foraging in natural ecosystem. Thus *T. itama, T. thoracica, T. atripes and T. peninsularis* are potentially to be domesticated and used for pollination service in agricultural ecosystem.

## 4 CONCLUSION

Pollination is critical for production and human livelihoods. Many ecosystem functions will collapse if pollination is not in place. Bees are the most important agent of pollination. In Malaysia, stingless could be important pollinator to replace honey bee if the later honey bee is declining as been reported (Kearns et al., 1998; Biesmeijer et al., 2006). At least 32 species of them were inventoried and at least four of them, *T. itama, T. thoracica, T. atripes and T. peninsularis* can be potentially domesticated for pollination service in agricultural ecosystem.

In order to sustain stingless bee pollination services in natural and agricultural and ecosystems, a greater appreciation of their multiple goods and services is necessary. Some of the issues need to be addressed. These issues are technology to domesticate them; capacity building to study them; and method to quantify their service needs to address. Likewise, stingless bee diversity and the factors that influence their decline and activity need to be examined. A management program that promotes the conservation and diversity of stingless bees through landscape management is necessary to optimize pollinator services in agricultural and other terrestrial ecosystems.

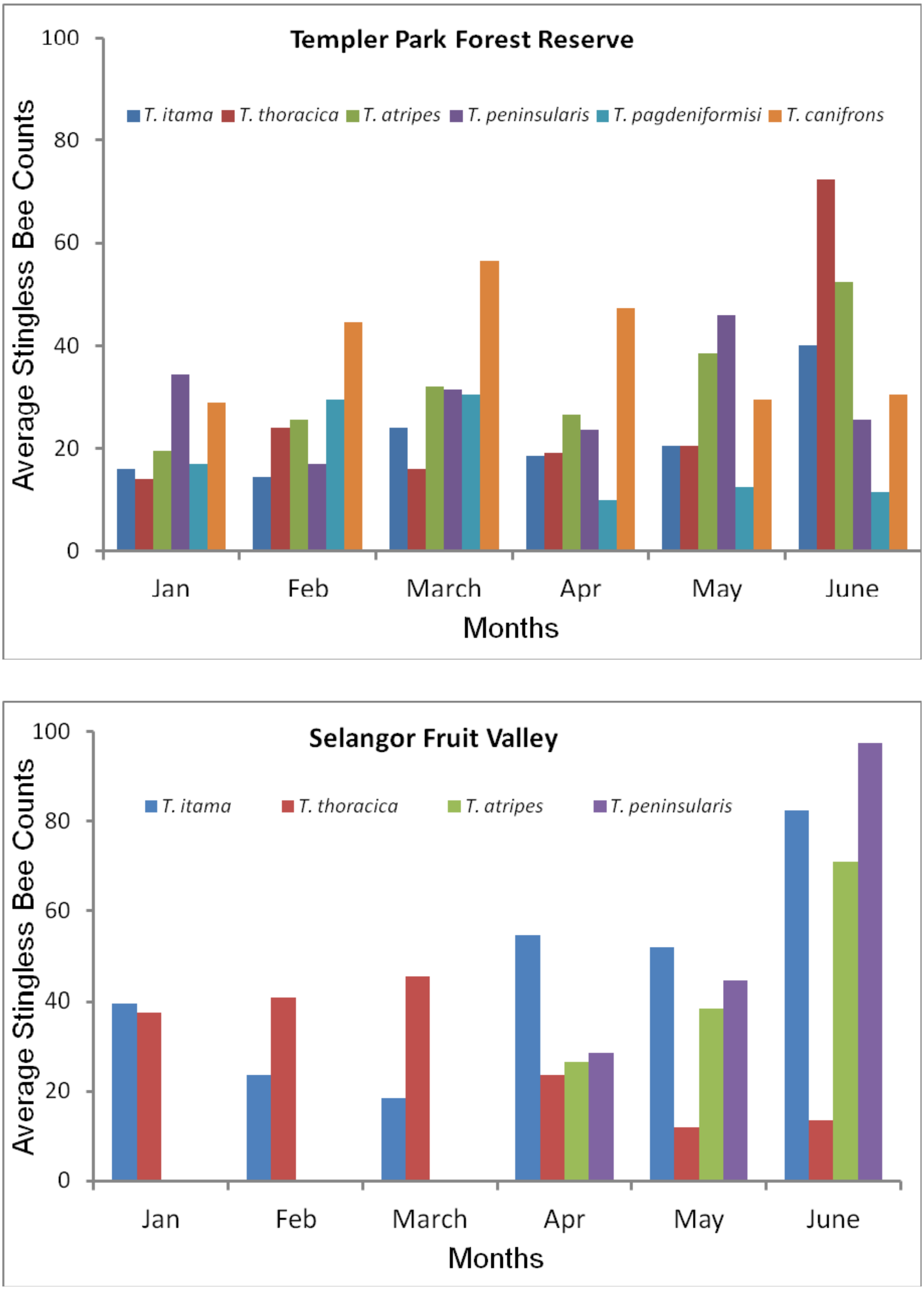


Figure 2. The diversity and abundance of stingless bees in natural and agricultural ecosystem.

## Acknowledgement

The authors wish to express sincere thanks to Mr Hamdan Sipon for their technical support. This project was funded by MARDI development fund.

## References

Biesmeijer, J.C., E.J. Slaa, M. Siqueira de Castro, B.F. Viana, A. Kleinert, and I.-F. V.L. 2005. Connectance of Brazilian social bee – food plant networks is influenced by habitat, but not by latitude, altitude or network size. Biota Neotrop 5:1-9.

Biesmeijer, J.C., S.P.M. Roberts, M. Reemer, R. Ohlemuller, M. Edwards, T. Peeters, A.P. Schaffers, S.G. Potts, R. Kleukers, C.D. Thomas, J. Settele, and W.E. Kunin. 2006. Parallel declines in pollinators and insect-pollinated plants in Britain and the Netherlands. Science 313:351-354.

Blanche, K.R., J.A. Ludwig, and S.A. Cunningham. 2006. Proximity to rainforest enhances pollination and fruit set in macadamia and longan orchards in north Queensland, Australia. Journal of Applied Ecology 43:1182-1187.

Daily, G.C., S. Alexander, P.R. Ehrlich, L. Goulder, J. Lubchenco, P.A. Matson, H.A. Mooney, S. Postel, S.H. Schneider, D. Tilman, and G.M. Woodwell. 1997. Ecosystem services: benefits supplied to human societies by natural ecosystems. Issues in Ecology:1-16.

Eltz, T., C.A. Brühl, Z. Imiyabir, and K.E. Linsenmair. 2003. Nesting and nest trees of stingless bees (Apidae: Meliponini) in lowland dipterocarp forests in Sabah, Malaysia, with implications for forest management. Forest Ecology and Management 172:301-313.

FA0. 2007. Pollinators: Neglected biodiversity of importance to food and agriculture CGRFA-11/07/Inf.15. Food and Agriculture Organization of United Nations, Rome, .

Gallai, N., J.-M. Salles, J. Settele, and B.E. Vaissière. 2009. Economic valuation of the vulnerability of world agriculture confronted with pollinator decline. Ecological Economics 68:810-821.

Heard, T.A. 1999. The role of stingless bees in crop pollination. Annual Review of Entomology 44:183-206.

Heithaus, E.R. 1979. Flower-feeding specialization in wild bee and wasp communities in seasonal neotropical habitats. Oecologia 42:179-194.

Kearns, C.A., D.W. Inouye, and N.M. Waser. 1998. Endangered mutulisms: The Conservation of Plant-Pollinator Interactions. Annu. Rev. Ecol. Syst. 29:83-112.

Klein, A.-M., B.E. VaissiÃ¨re, J.H. Cane, I. Steffan-Dewenter, S.A. Cunningham, C. Kremen, and T. Tscharntke. 2007. Importance of pollinators in changing landscapes for world crops. Proceedings of the Royal Society B: Biological Sciences 274:303-313.

Kukutani, T., T. Inoue, and Y. Maeta. 1993. Pollination of strawberry by the stingless bee, *Trigona minangkabao*, and the honeybee, *Apis mellifera*: An experimental study of fertilization efficience. Research in Population Ecology 35 95-111.

Mohd Norowi, H., B. Ithnin, and A.R. Mohd Syaifudin. 2008. Assessment of arthropod pollinator services in fruit ecosystem in Malaysia. CBD Technical Bulletin 34:44-49.

Momose, K., T. Yumoto, Nagamitsu, M. Kato, H. Nagamasu, S. Sakai, R.P. Harrison, A.A. Hamid, and T. Inoue. 1998. Pollination biology in a lowland Dipterocarp forest in Sarawak, Malaysia. I. Characteristics of the plant-pollinator community in lowland dipterocarp forest American Journal of Botany 85:1477-1501.

Osawa, N., and Y. Tsubaki, 2003. Seasonal variation and community structure of tropical bees in a lowland tropical forest of peninsular Malaysia: the impact of general flowering. In Okuda, et al. (eds.), Pasoh: Ecology of a Lowland Rain Forest in Southeast Asia. Tokyo. Springer. Pp. 315-324

Palma, G., J.G. Javier, Quezada-Euán, V. Meléndez-Ramirez, J. Irigoyen, G. R., G.R. Valdovinos-Nuñez, and M. Rejón. 2008. Comparative Efficiency of *Nannotrigona perilampoides*, *Bombus impatiens* (Hymenoptera: Apoidea), and Mechanical Vibration on Fruit Production of Enclosed Habanero Pepper. Journal of Economic Entomology 101:132-138.

Sakagami, S.F., T. Inoue, and S. Salmah, (eds.) 1985. Key to the stingless bee species found or expected from Sumatra, pp. 1-37-43. Kanasawa University Japan.

Samejima, H., M. Marzuki, T. Nagamitsu, and T. Nakasizuka. 2004. The effects of human disturbance on a stingless bee community in a tropical rainforest. Biological Conservation 120:577-587.

Schwarz, H.F. 1939. The Indon-Malaysan species of *Trigona*. Bulletin of The American Museum of Natural History LXXVI:83-141.

Sciencedaily. 2008. Economic Value Of Insect Pollination Worldwide Estimated At U.S. $217 Billion.

Slaa, E.J., L.A.S. Chaves, K.S. Malagodi-Bragac, and F.E. Hofsteded. 2006. Stingless bees in applied pollination: practice and perspectives. Apidologie 37:293-315.

Syed, R.A., I.H. Law, and V.R.H. Corley. 1982. Insect pollination of oil palm: introduction, establishment and pollinating efficiency of *Elaeidobius kamerunicus* in Malaysia. . Planter (Malaysia) 58:547-561.

Appendix A. Species of stingless bees recorded in Malaysia

| Number | Species | (Schwarz, 1939) | Specimens in MARDI insect Museum | (Osawa and Tsubaki, 2003) |
|---|---|---|---|---|
| 1 | *Trigona itama* | X | X | |
| 2 | *T. erythrogastra* | X | X | |
| 3 | *T. canifrons* | X | X | X |
| 4 | *T. fimbriata* | X | X | X |
| 5 | *T. thoracica* | X | X | |
| 6 | *T. fuscobalteata* | X | X | |
| 7 | *T. iridipennis* | X | X | |
| 8 | *T. geissleri* | X | X | X |
| 9 | *T. atripes* | X | X | X |
| 10 | *T. atripes var collina* | X | X | |
| 11 | *T. atripes var fuscibasis* | X | X | |
| 12 | *T. apicalis var smith* | X | X | |
| 13 | *T. apicalis var melanoleuca* | X | X | |
| 14 | *T. apicalis var peninsularis* | X | X | X |
| 15 | *T. scintillans* | X | X | |
| 16 | *T. pendleburyi* | X | X | |
| 17 | *T. nitiventris* | X | | |
| 18 | *T. ventralis* | X | X | |
| 19 | *T. terminata var smith* | X | X | |
| 20 | *T. terminata var latabalteata* | X | | |
| 21 | *T. minor sakagami* | X | X | |
| 22 | *T. rufibasalia* | X | X | |
| 23 | *T. moorei schwarz* | X | X | |
| 24 | *T. pagdeniformis* | | X | X |
| 25 | *T. minangkabau* | | X | X |
| 26 | *T. leeviceps* | | X | X |
| 27 | *T. nitidirentris* | | | X |
| 28 | *T. reepeni* | | X | |
| 29 | *T. pagdeni* | | X | |
| 30 | *T. melina* | | X | |
| 31 | *T. nitidiventris* | | X | |
| 32 | *T. klossi* | | X | |