

# SUSTAINING BEEHIVE-FENCE TO REDUCE ELEPHANT ENCROACHMENT IN OIL PALM PLANTATION

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## ABSTRACT

*Human-elephant conflict is among the important issues debated since the oil palm industry was established in Malaysia. Various mitigation methods have been implemented to reduce economic loss due to crop raiding by the elephants, but none seems to be highly effective. Hence, the beehive-fence (BHF) was implemented as an alternative control method in Ladang Jernih Oil Palm Plantation in Terengganu, Malaysia. However, data from previous BHF studies showed that the number of bee colonies had reduced over time due to various reasons. In this article, we present the challenges of sustaining the Asian honeybee, *Apis cerana*, colonies used for the BHF project in Ladang Jernih. We collected data on pests and predators, bee activity levels, food sources and the number of elephant encroachment incidents. Although the number of elephant encroachment incidents in Ladang Jernih was reduced, we found that the beehives faced a significantly high number of pest infestations. The activity levels of the bee colonies were also found to be passive due to limited food sources. We therefore conclude that the BHF may become another sustainable mitigation method to reduce elephant encroachment, but more attention must be given to the bee colonies to ensure the success of this eco-friendly mitigation effort.*

**Keywords:** *Apis cerana*, beehive-fence, human-wildlife conflict, Malaysia, oil palm.

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## INTRODUCTION

Human-wildlife conflict is a common issue when it comes to industrial, development, and agriculture practices. Certain activities of land development require deforestation which led to the loss of wildlife habitats, foraging sites and hunting areas. As such, the affected wildlife will enter farms or house perimeters during foraging. In the Malaysian oil palm industry, planters are required to follow the New Planting Procedures

(NPP) under the Roundtable on Sustainable Palm Oil (RSPO) standards, in which the primary forest, high conservation value (HCV) areas, high carbon stock (HCS) forests, peatland, fragile and marginal soils, as well as local people's lands should not be developed into oil palm planting area. Oil palm planting areas are either through the utilisation of idle land or conversion from other crops, primarily rubber and cocoa. Nevertheless, human-elephant conflict (HEC) is among the important issues that have been debated since the early days when the industry was first started (Ahmad Zafir and Magintan, 2016). This is perhaps unavoidable since most of the agricultural lands were adjacent to the forest areas where wildlife is abundant. Wild elephant encroachment and crop raiding commonly occur especially in the states of Sabah, Terengganu and Pahang.

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Various mitigation methods were implemented in Malaysia to minimise elephant encroachments such as digging trenches, electric fencing, elephant translocation, throwing firecrackers, night patrolling to chase the elephants, and even culling if deemed necessary (Ahmad Zafir and Magintan, 2016). However, none of the methods was found to be effective in the long-term. Another mitigation method like chilli-tobacco rope was found to be effective in preventing elephants from entering the farm but only works significantly better in the low-rainfall regions compared to medium and high-rainfall regions (Chelliah *et al.*, 2010).

Over time, elephants have become habituated to the methods and they constantly find ways to overcome them. In 2007, a new practice using honeybees as a natural deterrent to prevent wild elephant encroachment was introduced (King *et al.*, 2007). The project was originally performed in Kenya, Africa and further studies were conducted in other countries until today. The study yielded positive results where the number of wild elephant encroachments was reduced (King *et al.*, 2007; 2009; 2011; 2017). Wild elephants avoided contact with the beehive boxes, including the empty ones, which indicated that the elephants have already 'memorised' the previous bee attack experiences. The study was replicated and tested in other countries including Thailand (Dror *et al.*, 2020; van de Water *et al.*, 2020) and India (Nair and Jayson, 2016).

However, a model study has not been tested on large scale, particularly in the oil palm plantation areas. According to the Department of Wildlife and National Parks Peninsular Malaysia (PERHILITAN), in Malaysia, and HEC ranks second in the number of recorded cases. In Kemaman district in the state of Terengganu, HEC ranks seventh in the number of reported cases from 2006 to 2015 (Othman, 2016). Ladang Jernih in Kemaman, which is under Terengganu Development and Management Berhad (TDM), experienced significant economic loss due to serial elephant encroachments which caused severe damage, mostly to the young oil palms. Typical mitigation methods such as electric fences and trenches were not fully effective in preventing elephant encroachments. Hence, the beehive fencing method using the native honeybee species, *Apis cerana*, was introduced into Ladang Jernih as an alternative mitigation plan to deter crop raiding elephants. The method introduced by King *et al.* (2009) was modified to suit the local environment and the large-scale oil palm plantations. This new mitigation approach was chosen as it could be the best biological control method to reduce elephant encroachment incidents (Choong and Dayang Norwana, 2005). This is important since Malaysian oil palm planters are required to comply with the best practices of oil palm management and care

for the endangered species, as listed under the Malaysian Sustainable Palm Oil (MSPO) standard as well as to meet the RSPO standards.

A study by King *et al.* (2011) in northern Kenya using honeybees, *A. mellifera*, to deter elephants gave promising results in reducing elephant damage to plantation fields, which has indirectly guided a new non-lethal way to minimise human-wildlife conflict. The bees are likely effective to deter elephants due to their quick response to any disturbance, which in this case is the elephant (Collins *et al.*, 1980).

However, data from previous studies showed that not all beehives used in the beehive-fences (BHF) studies can be sustained (King *et al.*, 2011; Ngama *et al.*, 2016). Some of the colonies emigrated or abandoned their hives after a while due to a lack of food resources, predation by pests and diseases (Ruttner, 1988). Moreover, since this study was conducted in an oil palm plantation area which is adjacent to the forest reserve, we believed that the BHF containing *A. cerana* colonies installed in this area is prone to be infested and invaded by pests and predators which originated from the surrounding oil palm plantations and nearby forest reserve areas.

Predators of *A. cerana* are attracted to all parts of the bee colony, including larvae, pollen, honey and wax. Predators that usually invade bee colonies are wasps, hornets, ants and also vertebrates such as toads, frogs, lizards, geckos, rats, Asian bears, birds, as well as humans (Oldroyd and Wongsiri, 2006). Numerous types of pests can be found around the oil palm plantation area, such as the greater wax moth, *Galleria mellonella*, and the lesser wax moth, *Achroia grisella*. In addition, most of the flying honeybees are foragers and hence, they are more prone to predation by the Asian hornet, *Vespa velutina*, due to their pollen or nectar loads which can represent up to 40% extra body mass, thus, reducing their flying maneuverability to escape predators (Feuerbacher *et al.*, 2003). Moreover, to work efficiently, the beehive colony must be healthy and show high activity levels as stated by Woyke (1992). A colony's defence mechanism correlates with its beehive activity levels, which means that when they are highly active, the bees' reaction to attack any predator is also likely higher, as they possess stronger defence ability.

In this article, we present data on the challenges of sustaining beehives in oil palm plantation areas associated with the BHF project conducted in Ladang Jernih, Kemaman, Terengganu. This is the first BHF project, to our knowledge, performed in large agricultural areas. We conducted this study to determine the type of pests and predators that could be enemies to the bee colonies and the bee's activity levels after BHF installation in the oil palm plantation area. We also looked at the types of pollen collected by the bees to determine the food sources of the bees in the oil palm plantation areas. This study is vital to gain information on how to sustain

bee colonies in the agricultural field, especially in oil palm plantation areas that are usually located near the forest reserve. Finally, we also compared the number of elephant encroachment incidents in Ladang Jernih before and during this study was conducted, including the association between elephant encroachment with the bee activity levels. We believe that these findings are important for the future of the oil palm industry, especially to companies and smallholders who wish to use BHF as an alternative method to reduce HEC.

## MATERIALS AND METHODS

### Study Site

This study was conducted in Ladang Jernih, Kemaman, Terengganu, Malaysia (4° 25' 29.53" N, 103° 12' 51.78" E). This oil palm plantation area is under the management of TDM Berhad. Ladang Jernih comprises 2207.53 ha of mature oil palm areas and 405.40 ha of immature oil palm areas. The oil palm plantation area is adjacent to the protected forest reserve, Hutan Sungai Nipah and other neighbouring oil palm plantation areas which are also owned by TDM Berhad. Elephant encroachments occurred along the forest reserve borderline, marked as Point 1 to Point 5 (Figure 1).

### Experimental Set-up

Due to the very large plantation areas, it is uneconomical to build a BHF along the plantation perimeter. Hence, we only identified the active

entry points by the elephants and build the BHF along 60 m to cover this entrance. In total, there were five active entry points, and each point was marked as Point 1 to Point 5 (Figure 1). However, in this study, only Point 1, 2, 3 and 4 were installed with the BHF.

*Apis cerana* (Asian honeybees) was used in this study because this is a native bee species proven to be effective to deter elephants based on the study conducted in Kerala, India (Nair and Jayson 2016). Six hives containing colonies of *A. cerana* were hung 1 m above ground at each point, with a 10 m distance between hives as suggested by Nair and Jayson (2016). Each hive was labelled as Hive 1 to Hive 6 and all were connected with a rope following the method suggested by King *et al.* (2011) as shown in Figure 2. Varieties of flowers such as *Turnera subulata*, *Antigonon leptopus*, *Combretum indicum* and *Ixora coccinea* were planted surrounding the beehive areas. For integrated pest management purposes, these flowering plants were originally planted throughout the plantation area, to act as a biological control for oil palm pests such as bagworms. In total, 27 hives containing colonies of *A. cerana* (24 hives and three reinstallation hives at Point 1) were installed in Ladang Jernih throughout this study. The three additional hives installed at Point 1 in November were to replace the collapsed hives.

Four types of data collection were performed: a) pests and predators of *A. cerana*; b) bee activity levels; c) melissopalynology, and d) the number of elephant encroachment incidents. The data collections were conducted for eight months from August 2018 until March 2019.

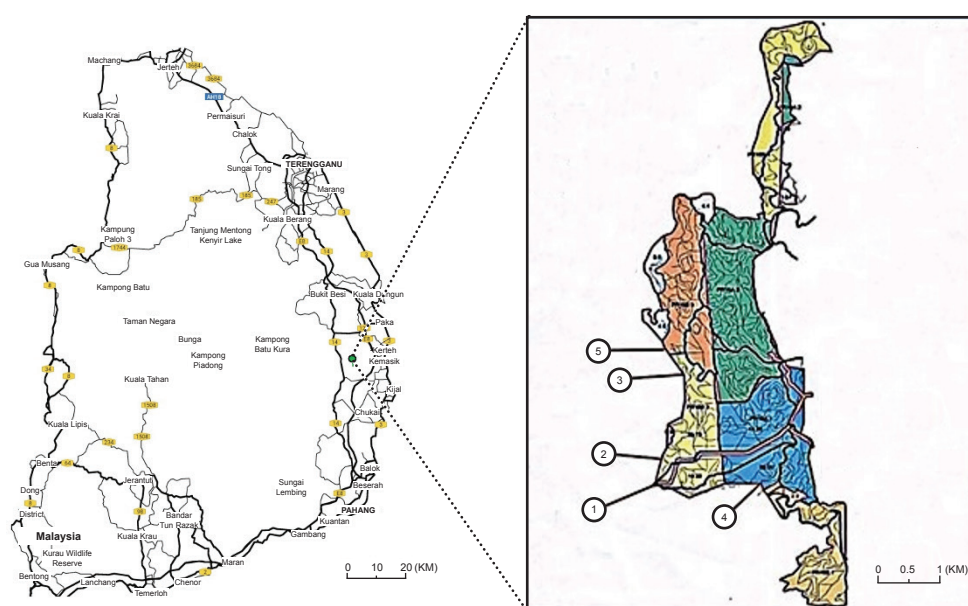


Figure 1. A map of Ladang Jernih in Kemaman, Terengganu (4.444° N, 103.257° E). Numbers shown in the circle indicate the active elephant encroachment points.





Figure 2. The beehive boxes installed as beehive-fence in the oil palm plantation at the four elephant entry points in Ladang Jernih. Each point was installed with six beehives and connected by a rope.

**Collection and observation of pests and predators of *A. cerana*.** Pest samples were collected to evaluate their effects on the sustainability of bee colonies throughout this project. Pest observation and collection were done from three sources: Outside the beehives, inside the beehive boxes and from the trail cameras. The trail cameras were used to gather digital proofs (photos and videos) of predators that disturbed the BHF, especially at night.

Each beehive was inspected and observed monthly for the presence of any pests. Pictures of pests present outside the beehives were captured and recorded. To inspect pests inside the beehives, the lids of the beehive boxes were carefully opened. Frames (four to five frames per hive) were lifted one after another to inspect the presence of any pest. Pictures of pests present were captured for record purposes and the samples were collected for identification. All pests found in the hives were collected using a pair of forceps and were put into a killing jar before being brought back to the laboratory for further identification. Meanwhile, any pest's larvae found inside the hives were reared in the laboratory until the adult stage to ease the identification process. After all, pests were collected, hives were cleaned using brushes and the frames were placed in their original positions inside the hive before they were closed. It is impossible to count the individual number of certain species of the pests such as ants. Hence, any beehive that was infested by ants were counted as one, for each ant species.

Any larvae found within the honeycomb and beehive box were collected along with the whole bee comb as their food source. Based on the rearing method by Steyskal *et al.* (1986) and Basari *et al.* (2019), the larvae were reared in a 2 L jar and sealed with a muslin cloth. Then, the specimens were left in the laboratory at room temperature ( $27^{\circ}\text{C} \pm$

0.05) and observed regularly until they emerged into adult forms. Once they have entered the adult stage, the insects were put into a killing jar and pinned at their thorax for further identification. The number of the wax moth found in the beehive was based on the number of larvae found during the data collection.

To determine the predators of the beehives at night, two wildlife trail cameras (Toguard, 14 MP 1080P) were installed at strategic spots at each point. The night vision cameras were set up at chest height to ensure a wide range of observations over the six colony-containing hives installed at each point. The cameras were programmed to capture videos for 10 min, with 1 s intervals between each video. All evidence captured was observed and analysed for the existence of pests and predators during the day and night.

**Bee activity levels.** For each beehive, the inbound and outbound movements of the beehives were recorded for 10 min using a camera (Nikon Coolpix L340). Data were recorded from 1000 hr when they were active (Koetz, 2013). The camera was pointed towards the hive entrance. The bee's activity level was then calculated based on the number of inbound and outbound individuals. Bee activity levels were calculated using the method put forward by Ngama *et al.* (2016), by estimating the number of bee movements per minute ( $\text{b.mvt min}^{-1}$ ). The classification was done using the natural breakpoint of  $70 \text{ b.mvt min}^{-1}$ . If the movement is less than  $70 \text{ b.mvt min}^{-1}$ , it will be classified as a "low" activity level, whereas movement of more than  $70 \text{ b.mvt min}^{-1}$  will be classified as a "high" activity level.

**Melissopalynology analysis.** The bee activity level (*i.e.*, active or weak) could be due to many reasons and one of the reasons is the availability of food sources. Bee colonies might emigrate to new nesting sites or become less active if the food sources in the area are scarce. Hence, melissopalynology analysis was also conducted in this study to determine the relationship between the bee activity levels and food availability in the oil palm area. Samples of pollens were collected monthly from August 2018 until January 2019. Three hives were selected randomly on each sampling for their pollen load. The pollens were acquired directly from the forager bees, by using insect nets inside the hive and from pollen combs or beebread, by using forceps. Pollen samples were collected using sterilised forceps and were stored in individual glass vials of 5 mL capacity with 70% alcohol. Three to five samples were taken from each hive. Altogether, 30 samples were collected.

The reference samples of dominant vegetation in the study area were collected using the sampling methods by Azmi *et al.* (2015). Flower buds of

dominant species found in the apiary were plucked cautiously and were preserved in labelled vials containing 70% ethanol. The ethanol was used to ensure that the flower buds collected were maintained in good condition. The preserved pollens were then transferred using a micropipette onto haemocytometer slides. Five replicates of slides were prepared for each vial, to provide descriptive coverage of pollens collected by each honeybee.

**Number of elephant encroachment incidents.** Each elephant entry point was monitored visually, and camera traps were also checked daily to determine any sign of elephant encroachment. The elephant encroachment incidents at each entry point were recorded daily. The number of elephant encroachment incidents eight months before the beehive installation (August 2017 - March 2018) *vs.* the number of elephant encroachment incidents after the commencement of the BHF project (August 2018 - March 2019) were then compared. Finally, the number of elephant encroachments against the pest occurrences and sustained beehives were plotted.

### Data Analysis

A Chi-Square test for relatedness was conducted to determine the relationship between pest occurrences and sustained hives towards the number of elephant encroachment. Chi-Square goodness of fit test was also conducted to analyse the number of elephant encroachment incidents before and after the BHF installation and the frequency of pest occurrence and the number of pollen loads between months. All analyses were conducted using SPSS v. 24 (IBM® software).

## RESULTS AND DISCUSSION

### Pest and Predators of *A. cerana*

Overall, 17 species of pests and predators were observed invading *A. cerana* hives in Ladang Jernih (Table 1). All these pests were found either living inside the beehives or preying on the bees outside the hives. *Rattus tiomanicus* and many species of ants were found inhabiting abandoned beehives.

The bee colonies suffer from the attack of various types of insects and vertebrates. For instance, the results showed that wasps, geckos, frogs, ants and wax moths were present in a vast number and very commonly encountered. This was most likely due to the location of the oil palm areas which are adjacent to Hutan Simpan Sungai Nipah, Kemaman, Terengganu. Hence, many predators such as predatory insects, geckos, rats and frogs took advantage to invade and prey upon the bee colonies in the beehives installed in Ladang Jernih. The number of pests recorded was the highest in September, in which ants and cockroaches especially in Point 2 and Point 3 were abundant followed by geckos in Point 1 and Point 4. The sustained colonies were declining each month, causing it necessary to reinstall three new colonies in Point 1. Besides, the sustained hives seem to have a declining pattern throughout the project period (August 2018 - January 2019). We believed that this was caused mainly by the pests and predators that disturbed the bee colonies. Wax moths were the most frequent pests recorded in this project and they could be the greatest contributors to the emigration of the bee colonies as also suggested previously by Kwadha *et al.* (2017), likely causing most of the colonies installed in this study to become less active and finally collapse.

TABLE 1. PESTS AND PREDATORS FOUND INSIDE AND OUTSIDE BEEHIVES IN LADANG JERNIH OIL PALM PLANTATION AREA

Location	Pests (Order/ Common name)
Inside hive	<i>Periplaneta americana</i> (Blattodea/ American cockroach) <i>Galleria mellonella</i> (Lepidoptera/ Greater wax moth) <i>Achroia grisella</i> (Lepidoptera/ Lesser wax moth) <i>Rattus tiomanicus</i> (Rodentia/ Malaysian wood rat)
Inside and outside hive	<i>Myrmica</i> sp. (Hymenoptera/ Ant) <i>Paratrechina longicornis</i> (Hymenoptera/ Black crazy ant) <i>Tetramorium</i> sp. (Hymenoptera/ Ant) <i>Solenopsis geminata</i> (Hymenoptera/ Fire ant) <i>Oecophylla smaragdina</i> (Hymenoptera/ Weaver ant) <i>Monomorium floricola</i> (Hymenoptera/ Ant) <i>Monomorium pharaonis</i> (Hymenoptera/ Pharaoh ant) <i>Camponotus</i> sp. (Hymenoptera/ Ant) <i>Anoplolepis gracilipes</i> (Hymenoptera/ Yellow crazy ant) <i>Hemidactylus frenatus</i> (Squamata/ Common house lizard) <i>Hylarana</i> sp. (Anura/ Frog)
Hive perimeter/ outside	<i>Vespa tropica</i> (Hymenoptera/ Tropical wasp) <i>Gekko</i> sp. (Squamata/ Lizard)
Video trail camera	<i>Sus scrofa</i> (Artiodactyla/ Wild boar)

We also found that *G. mellonella* (Greater wax moths) appears to be more abundant compared to *A. grisella* (Lesser wax moths). The two species of wax moths can be easily identified by examining the presence of four stemmata on the larvae of *G. mellonella* (Ellis *et al.*, 2013). A study by Oldroyd and Wongsiri (2006) also yielded a similar result, with the discovery of ants, cockroaches, geckos, frogs, wasps and rats as pests of *A. cerana*. Rats infestation might seem to be rare or unusual for *A. cerana* colonies. However, the occurrence of this pest in this study is expected, since the study site is located within the oil palm plantation areas. Previous studies in several localities in Malaysia had reported *R. tiomanicus* as the most common Murids rodent caught in oil palm plantations, other than *R. argentiventer* and *R. rattus* (Hafidzi and Saayon, 2001; Mohd-Azlan *et al.*, 2019; Puan *et al.*, 2011). *R. tiomanicus* is well adapted in various agricultural habitats and is said to have good adaptation in the oil palm plantation areas due to its arboreal habits (Hafidzi and Saayon, 2001). We believe that the rats' infestation upon *A. cerana* hives in the present study occurred because they required shelter and protection for their young. In general, the number of pests correlated with the number of sustained hives. Based on the results shown in Figure 3, the increment in the number of pests disturbing the colonies had led to the declining pattern of sustained hives. In short, it can be concluded that the number of sustained beehives decreased when the number of pests increased.

### Number of Pests vs. Sustained Hives and Number of Elephant Encroachment Incidents in Each Sampling Point

As shown in Figure 3, it can be seen that when the number of pests and predators increased, the number of sustained beehives decreased. There was a significant difference in the number of pests infesting beehives between months [ $\chi^2(18) = 32.90$ ,  $p=0.02$ ]. Moreover, when the number of pests was high and sustained hives decreased, the number of elephant encroachment incidents also increased [ $\chi^2(1, N=65) = 20.53$ ,  $p<0.001$ ].

Eight months after the BHF installation, the number of elephant encroachment events in Ladang Jernih had reduced from 31 times to only 16 times. Even though elephant encroachment incidents were recorded almost every month before and after the BHF installation, the encroachment events were clearly shown to decrease significantly after the BHF were installed [ $\chi^2(63) = 15.254$ ,  $p<0.001$ ]; Table 2.

Oil palm plantations serve as a place for elephants to find food resources, which are the palm seedlings. The availability of palm seedlings has caused the elephants to intrude into oil palm areas and damage the crops (Blake, 2002). The common control methods that are still being used such as electric fences and trenches are considered harmful as they tend to cause injuries to the elephants. These mitigation methods also demand a high cost of maintenance and are

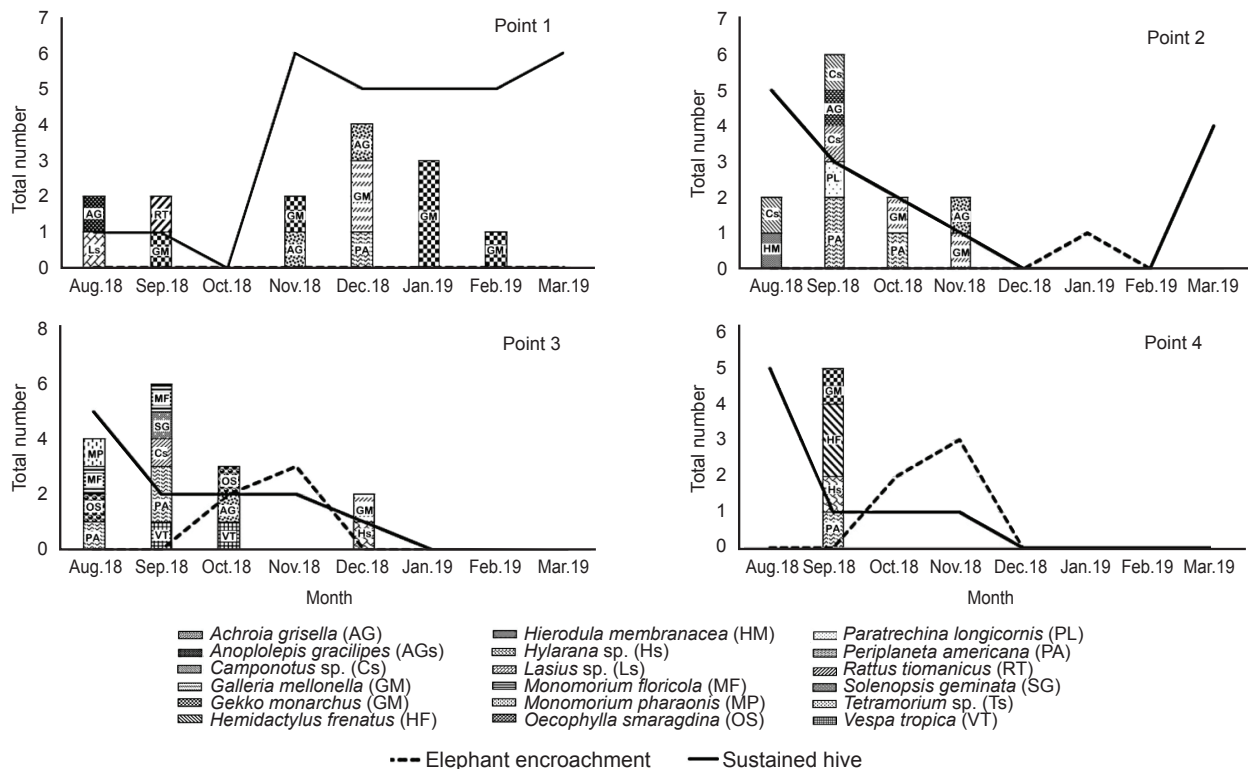


Figure 3. The number of pests which infested the beehives in each month vs. the number of sustained beehives and elephant encroachment in Ladang Jernih. The existence of ants in the beehives was counted as one pest per species. The common name of each species can be referred to Table 1.



therefore considered uneconomical to be practised over a long time.

The results shown in Figure 3 also indicated that the number of elephant encroachment incidents varies between months, with the highest frequency occurring in October and November 2018. Digital proofs in the form of photos and videos indicated that encroachment had occurred several times throughout this project, in which elephants (a group usually consisting of two to seven individuals) most frequently intrude, followed by wild boars. This could be one of the reasons for bee colonies to be unsustainable in the study area. The bees tend to emigrate after the disturbance following these encroachments, as well as the occurrence of pests and predators in their hives. However, many other factors could also contribute to the emigration of the bees such as food availability, which will be discussed below.

### The Mean Activity Level of *A. cerana* in Ladang Jernih

Table 3 showed the mean activity level of bee colonies placed at each sampling point. The activity levels of the bee colonies were less than 70 b.mvt min<sup>-1</sup>, considered low activity. This

indicates that the colonies became less active in foraging after they were placed in Ladang Jernih.

Our results also showed that most of the honeybee colonies showed less than 70 b.mvt min<sup>-1</sup>, which indicates that most of the hives were classified as having low activity levels. Although it is known that *A. cerana* migrated more often (Olydrod *et al.*, 2006) when compared to *A. mellifera*, we believe that pest infestation was one of the factors that lead to the decreasing value of *A. cerana* activity. For example, research by Hyatt (2011) found that, after being attacked by ants and disturbed by the local people, *A. cerana* colonies then deserted their hives within a short time. *A. cerana* was more stressed by the predation pressure compared to the temperate honeybee species, *A. mellifera* (Koetz, 2013). The study by Koetz (2013) showed that honeybees tend to be stressed by ant infestation. Based on our data, many species of ants were found infesting the beehives in Ladang Jernih, especially predatory ants such as the weaver ant (*O. smaragdina*) and the yellow crazy ant (*A. gracilipes*). Honeybees also have many other predators such as wasps and hornets, that often attack the bee foragers. These predators often attack almost all parts of the colony such as adult

TABLE 2. THE NUMBER OF ELEPHANT ENCROACHMENT INCIDENTS IN EIGHT MONTHS BEFORE AND AFTER BHF INSTALLATION IN LADANG JERNIH, KEMAMAN, TERENGGANU

Before BHF		After BHF	
Months	Encroachment No.	Months	Encroachment No.
Aug. 2017	0	Aug. 2018	0
Sept. 2017	8	Sept. 2018	0
Oct. 2017	9	Oct. 2018	4
Nov. 2017	8	Nov. 2018	9
Dec. 2017	9	Dec. 2018	1
Jan. 2018	9	Jan. 2018	1
Feb. 2018	3	Feb. 2018	0
Mar. 2018	1	Mar. 2018	1
Total	47		16

TABLE 3. THE MEAN ACTIVITY LEVEL OF *A. cerana* CALCULATED IN BEE MOVEMENTS PER MINUTE (b.mvt min<sup>-1</sup>) FOR EACH SAMPLING POINT (PT) IN EACH MONTH IN LADANG JERNIH

Month	Pt. 1	Pt. 2	Pt. 3	Pt. 4
Aug. 2018	14.70*	3.18 ± 2.69	3.24 ± 1.82	0.00**
Sept. 2018	0.27 ± 0.27	4.58 ± 1.92	13.67 ± 12	0.00**
Oct. 2018	0.0**	2.83 ± 2.01	1.370 ± 1.11	0.00**
Nov. 2018	41.89 ± 5.21	0.35*	0.67 ± 0.54	0.97*
Dec. 2018	20.70 ± 7.68	0.00**	0.16*	0.00**
Jan. 2019	13.87 ± 9.42	0.00**		
Feb. 2019	0.92 ± 0.31	0.00**		
Mar. 2019	28.95 ± 14.4	1.12 ± 1.01		

Note: Colonies at Pt. 3 and 4 had sustained until December 2018 only.

\*Only one colony showed inbound and outbound activity.

\*\*Colonies were too weak with no inbound and outbound activity recorded.

honeybees, larvae and pupae, and the food sources of the honeybees which is pollen and honey (Fuchs and Tautz, 2011). The pressure from these pest infestations gives a bad impact on *A. cerana* because it influences the bee's decision to choose a nesting site, the size of the population itself and it can also alter the behaviour of the workers (Seeley *et al.*, 1982). For example, a study conducted by Visscher and Seeley *et al.* (1982) in Northeast Thailand found that 10% of the observed honeybee colonies had to migrate due to pressure from predators.

### Floral Diversity of Pollens Collected by *A. cerana* in Ladang Jernih

Based on the pollen analysis, there were 12 types of pollen and five unidentified pollens attached to the bees' corbiculae (Figure 4). The most dominant pollens (more than 45% of pollen grains counted) collected from the bees' corbiculae came from *Mimosa pudica*, *T. subulata* and *Melastoma malabatricum*, but no oil palm pollen was collected from the bees. A number of pollens for different species of flowers collected from the forager bees were significantly different ( $\chi^2(16) = 3573.03$ ,  $p \leq 0.01$ ).

*Apis cerana* colonies in Ladang Jernih also faced other problems such as a lack of pollen and nectar sources for their food production. According to Partap (2011), *A. cerana* is an active crop pollinator and this species can forage through diverse species of vegetable and fruit crops. However, because most of the flowering plants were newly planted in the study area, the production of nectar and pollen from the plants may not have been enough to support the number of food sources needed by the *A. cerana* colonies. Furthermore, most of the oil palm trees in our study area were also newly

planted and did not produce flowers. Although the bees can forage from the wildflowers within the neighbouring forest area, the foraging distance of *A. cerana* which is only about 200-900 m from their hives (Corlett, 2011) may limit their options. *A. cerana* is known to forage in a short distance as compared to the western honeybee, *A. mellifera* and is likely to abscond its colony under unfavourable conditions such as lack of food sources (Gratzer *et al.* 2019). Hence, the bees chose to emigrate to a new location that could give them more benefits in terms of food supply and colony sustainability. For honeybees, migration factors are related to lacking food resources and the surrounding environmental conditions of that area (Koetz, 2013). This situation is supported by *A. cerana* themselves because they are usually not prepared for untoward conditions, making them not had enough food sources when the condition is unfavourable to them (Nanork *et al.*, 2006). Research by Chen *et al.* (1995) also stated that *A. cerana* is likely to abscond their hives influenced by the flower blooming season. The bee colonies tend to migrate when the number of pollen-carrying workers drops, and the honey, eggs and pollen stores decrease rapidly (Pokhrel *et al.*, 2006).

### CONCLUSION

Our results showed that the number of elephant encroachment incidents had significantly reduced at each entry point after the BHF's were installed. We believe that the presence of the beehives at the elephant entry points had likely contributed to the reduction in elephant encroachments at Ladang Jernih. However, due to the pest infestations and lack of food, many bee colonies struggled to persist

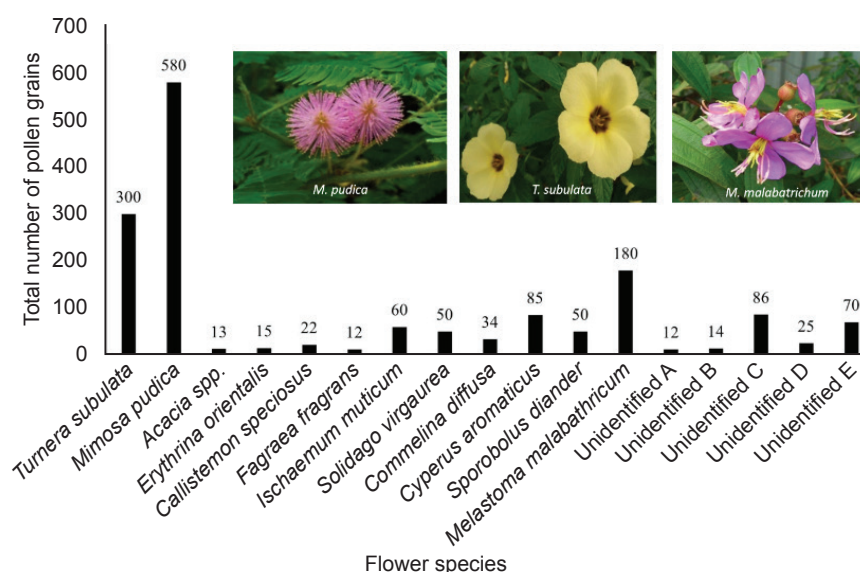


Figure 4. Total number of pollen grains based on plant species foraged by *A. cerana* at Ladang Jernih from August 2018 until January 2019.



in the area. When the number of active bee colonies reduced, the number of elephant encroachment incidents also started to increase. Hence, having a full-time caretaker(s) is crucial to ensure the persistence of the bee colonies in the oil palm areas. The bee colonies need to be delicately maintained, particularly during the initial phase of the beehives instalment, since disturbance from other animals as well as lack of food sources might hinder the establishment of the introduced colonies. We are aware that more research needs to be done in the future to support our findings, particularly to look at the effects of the BHF on elephant encroachments over a long time. Nevertheless, we hope that this study could help future planning in developing eco-friendlier pest management in oil palm plantation areas.

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